

2

Life History and Population Dynamics of Cerambycids

Robert A. Haack
USDA Forest Service
Lansing, Michigan

Melody A. Keena
USDA Forest Service
Hamden, Connecticut

Dominic Eyre
Defra, Department for Environment, Food & Rural Affairs
Sand Hutton, York, UK

CONTENTS

2.1	Introduction.....	71
2.2	Larval and Adult Feeding Habits.....	72
2.3	Oviposition, Fecundity, and Egg Development.....	72
2.4	Larval Development and Voltinism.....	76
2.5	Pupal Development and Adult Emergence.....	79
2.6	Overwintering, Quiescence, and Diapause.....	81
2.7	Dispersal.....	85
2.8	Adult Longevity.....	88
2.9	Population Dynamics in Relation to Environmental Conditions.....	89
2.10	Final Note.....	93
	Acknowledgments.....	94
	References.....	94

2.1 Introduction

The Cerambycidae comprise a large and diverse family of beetles with more than 36,000 species recognized worldwide (see Chapter 1). Cerambycids vary greatly in adult body length, from as short as 1.5 mm long in the Caribbean twig-boring lamiine *Decarthria stephensi* Hope (Villiers 1980; Peck 2011) to as long as 167 mm in the prionine *Titanus giganteus* (L.) (Bleuzen 1994), the larvae of which likely develop in decaying wood in South American rain forests. Cerambycids are native to all continents with the exception of Antarctica and can be found from sea level [e.g., the cerambycine *Ceresium olidum* (Fairmaire) in the Society Islands and Fiji; Blair 1934] to alpine sites as high as 4200 m (e.g., the cerambycine *Molorchus relictus* Niisato in China [Niisato 1996; Pesarini and Sabbadini 1997] and the lamiine *Lophopoeum forsteri* Tippmann in Bolivia [Tippmann 1960]). In this chapter, we will discuss the types of habitats commonly occupied by cerambycids, the development of the immature stages, diapause, adult dispersal and longevity, and population dynamics.

2.2 Larval and Adult Feeding Habits

Nearly all cerambycids are phytophagous as both adults and larvae. One exception is exemplified by adults in the cerambycine genus *Elytroleptus* that mimic and prey on adult lycid beetles (Eisner et al. 2008; Grzymala and Miller 2013). Likewise, although cerambycid larvae generally are considered phytophagous, facultative inter- and intraspecific predation has been observed when larvae encounter other individuals while constructing galleries within their host plants (Dodds et al. 2001; Ware and Stephen 2006; Schoeller et al. 2012).

A detailed account of the feeding biology of cerambycids is presented in Chapter 3 of this book; therefore, only a brief summary will be presented here. Cerambycids utilize a wide variety of plant species as larval hosts, including both monocots and dicots, and many species are pests of forest and urban trees (see Chapter 11) and crops (see Chapter 12). Worldwide, the vast majority of cerambycids develop in woody plants, especially trees. Almost every plant part is consumed by at least a few cerambycid species, with the vast majority developing in the stems, branches, and roots. Moreover, nearly every plant tissue is consumed by cerambycid larvae, with some species feeding mostly in the bark, some mostly in sapwood, others mostly in heartwood, and still others mostly in pith. Most cerambycid larvae develop within the tissues of their host plant, but there are some soil-dwelling species that feed externally on plant roots. With respect to host condition, some species develop in living hosts, although others are found in recently dead or even well-decayed hosts (Hanks 1999). In addition, some species prefer to infest dry wood (Hickin 1975). As for the larval host range, some cerambycids are highly monophagous, feeding on a single species or genus of plants, although others develop on several genera within a single family, and still others are highly polyphagous, developing in several plant families (Craighead 1923; Duffy 1953; Linsley 1959, 1961). There also is great variation in the types of food consumed by adult cerambycids, with some apparently not feeding at all, while others feed on flowers, bark, foliage, cones, sap, fruit, roots, and fungi (Trägårdh 1930; Butovitsch 1939; Duffy 1953; Linsley 1959, 1961; also see Chapter 3).

2.3 Oviposition, Fecundity, and Egg Development

Cerambycids oviposit on, in, or near their larval host plants (Trägårdh 1930; Butovitsch 1939; Duffy 1953; Linsley 1959, 1961). The behaviors displayed during oviposition also vary greatly among species. For example, in many Lepturinae and Prioninae, females simply push their ovipositor into the substrate when laying eggs, which is often soft and partially decayed wood or soil near the base of the larval host plant. Some cerambycids oviposit on the outer surface of their hosts (e.g., some Cerambycinae and Spondylidinae), while most non-Lamiinae cerambycids that infest woody plants lay eggs under bark scales or in bark crevices (Linsley 1959). In the Lamiinae, however, females typically prepare the oviposition site with their mandibles by chewing a slit or pit through the outer plant tissues into which they oviposit (Figures 2.1 and 2.2), while some lamiines use the tip of their abdomen to enlarge the oviposition site after first using their mouthparts (Linsley 1959).

Members of several cerambycid subfamilies oviposit in the entrance holes, exit holes, and other gallery structures created by various bark- and wood-boring insects (Linsley 1959). For example, Youngs (1897) reported on the lepturine *Anthophylax attenuates* (Haldeman) ovipositing in the galleries of the ptinid beetle *Ptilinus ruficornis* Say, apparently by inserting their ovipositor into the exit holes. Similarly, some members of the lamiine genus *Acanthocinus* construct their oviposition pits over bark beetle (Scolytinae) entrance holes and ventilation holes (i.e., the holes constructed by bark beetles along the length of their egg galleries that extend into the outer bark). For example, 56% of the oviposition pits made by *A. aedilis* (L.) in Europe and 99% of the oviposition pits made by *A. nodosus* (F.) in the southern United States were centered over bark beetle entrance holes and ventilation holes on infested pine trees (Schroeder 1997; Dodds et al. 2002).

Relatively few cerambycids oviposit directly on wood that is bark free (Duffy 1953; Linsley 1961). The cerambycine *Hylotrupes bajulus* (L.) is one exception in that females lay batches of eggs directly in cracks and crevices on exposed wood, primarily the sapwood of various conifers (Duffy 1953).

Some adult females girdle the host tissue with their mouthparts prior to oviposition, especially twigs and small-diameter branches. Twig girdling is common among the two lamiine genera *Oberia* and



FIGURE 2.1 Adult female of the lamiine *Anoplophora glabripennis* (Motschulsky) ovipositing on a branch of Norway maple (*Acer platanoides* L.) in the United States. (Courtesy of Melody Keena [Bugwood image 5431704].)



FIGURE 2.2 Adults and oviposition pits of the lamiine *Anoplophora glabripennis* on maple (*Acer*) in New York. (Courtesy of Kenneth Law [Bugwood image 0949056].)

Oncideres, with *Oberea* females tending to oviposit below the girdle (i.e., toward the trunk, proximal) while *Oncideres* females oviposit above the girdle (i.e., toward the branch tip, distal). Solomon (1995) provided details on the girdling behavior of several woody dicot-infesting, North American species, including *Oberea bimaculata* (Olivier), *O. ocellata* Haldeman, *O. ruficollis* (Fabricius), *O. tripunctata* (Swederus), and *Oncideres cingulata* (Say), *O. pustulata* LeConte, *O. rhodosticta* Bates, and *O. quercus* Skinner. Typically, for the *Oberea* and *Oncideres* species listed here, the *Oberea* adult females first chew two

rings of punctures around the stem or twig about 13–25 mm apart and then chew a pit between the two rings and oviposit a single egg with the resulting larva tunneling downward (Figure 2.3). By contrast, *Oncideres* females girdle small to large branches (usually 5–20 mm, but up to 65 mm in *O. pustulata*) by chewing a ring around the circumference of the branch deep into the xylem tissue (Figure 2.4). *Oncideres* females usually girdle first and then oviposit in the branch, laying eggs singly in bark slits but often multiple eggs per branch (Rogers 1977a; Solomon 1995). The girdling of a branch appears to benefit the cerambycid larvae by reducing host defenses and elevating the nutritional quality of the host tissues (Forcella 1982; Rice 1995; Hanks 1999).

Fecundity in the Cerambycidae varies considerably among species from tens of eggs per female to several hundreds. Duffy (1953) warned, however, that field estimates often underestimate true total fecundity because eggs of cerambycids are often well concealed, making accurate counts difficult. A few examples of average lifetime fecundity based on laboratory studies are 80 eggs for the cerambycine *Megacyllene robiniae* (Galford 1984), 119 eggs for the cerambycine *Enaphalodes rufulus* (Haldeman) (Donley 1978), 133 eggs for the lamiine *Glenea cantor* (F.) (Lu et al. 2013), 159 eggs for the spondyliid *Arhopalus ferus* (Mulsant) (Hosking and Bain 1977), 161 eggs for the cerambycine *H. bajulus* (Cannon and Robinson 1982), 165 eggs for the lamiine *Neoptychodes trilineatus* (L.) (Horton 1917), 200–451 eggs for the lamiine *Monochamus carolinensis* (Olivier) (Walsh and Linit 1985; Zhang and Linit 1998), 250–350 eggs for the prionine *Prionoplus reticularis* White (Rogers et al. 2002), and 581 eggs for *M. alternatus* Hope (Zhang and Linit 1998). In a study using 15 field-collected prionine *Prionus laticollis* (Drury) adult females, Farrar and Kerr (1968) reported that on average they laid 388 eggs but retained an average of 255 eggs, with one female having a total of 1,211 eggs (laid and unlaidd).

Eggs usually are shades of white to yellow when first deposited and vary in length from under 0.5 mm to more than 1 cm in the prionine *T. giganteus* (Duffy 1953). Cerambycid eggs typically are elongate, usually being at least twice as long as broad (Butovitsch 1939; Figure 2.5). For example, based on data



FIGURE 2.3 Typical oviposition damage by the lamiine *Oberea perspicillata* Haldeman on its larval host *Rubus* in which the adult female makes two rows of punctures that encircle the stem and then lays an egg in the stem between the punctures. Larval frass is being extruded from the oviposition hole. (Courtesy of Bruce Watt, photo taken in Maine, USA. [Bugwood image 5507306].)



FIGURE 2.4 Typical oviposition damage by an adult female of the lamiine *Oncideres cingulata* (Say) on one of its larval hosts, *Carya*, in the eastern United States. Females first girdle the twigs or small branches by chewing a ring around the twig's circumference and then laying one or more eggs in the distal portion of the branch. The girdled branches eventually fall to the ground and the larvae develop within them. (Photo from the USDA Cooperative Extension Slide Series [Bugwood image 1435156].)



FIGURE 2.5 Egg of the spondylidine *Tetropium fuscum* (Fabricius) with the larva visible inside. (Courtesy of Jessica Price, photo taken in Canada [Bugwood image 5331003].)

in Duffy (1953) and Rogers et al. (2002), eggs average 1.1 mm long and 0.3 mm wide at their greatest width for the cerambycine *Molorchus minor* (L.), and similarly 1.5 and 0.5 mm for the parandrine *Neandra* (= *Parandra*) *brunnea*, 2.4 and 0.4 mm for the prionine *P. reticularis*, 3.1 and 1.5 mm for the prionine *Ergates spiculatus* (LeConte), and 4.1 and 0.5 mm for the prionine *Prionus coriarius* (L.).

Eggs usually are laid singly or occasionally in small clusters. For example, Walsh and Linit (1985) examined 652 oviposition pits constructed by the lamiine *M. carolinensis* and found that 89 pits had no eggs, 559 had one egg, and 4 had two eggs. Similarly, eggs mostly were laid singly by the branch-borer cerambycine *Osphranteria coerulea* Redtenbacher but occasionally in groups of two to three (Sharifi et al. 1970). By contrast, in the cerambycine *Phoracantha semipunctata* (F.), eggs commonly are deposited under bark in groups of 3–30 eggs (Scriven et al. 1986).

Most reviews state that cerambycid eggs usually hatch in a few days or up to four to five weeks at times, with two weeks being average (Craighead 1923; Butovitsch 1939; Duffy 1953; Linsley 1961). Data on the timing of egg hatch from several field and laboratory studies are listed in Table 2.1. For the field studies presented, the shortest incubation period was three to seven days for the lamiine *Nealcidion deletum* (Bates) in Guyana (Cleare 1931), and one of the longest was 22–24 days for the lamiine *Apriona germari* Hope in India (Hussain and Buhroo 2012). For the laboratory studies, which were conducted at temperatures ranging from 15°C to 34°C, the shortest average time to egg hatch was four days for the lamiines *Dectes texanus* LeConte at 27°C (Hatchett et al. 1973), *Phytoecia rufiventris* Gautier at 30°C (Shintani 2011), and *M. carolinensis* at 34°C (Pershing and Linit 1986). By contrast, some of the longest average times to egg hatch were 54 days for the lamiine *Anoplophora glabripennis* (Motschulsky) at 15°C (Keena 2006) and 55 days for the prionine *P. laticollis* at 16°C (Farrar and Kerr 1968). In addition, Keena (2006) reported that the average time to egg hatch for *A. glabripennis* was 25 days at 20°C, 15 days at 25°C, and 13 days at 30°C (Table 2.1).

2.4 Larval Development and Voltinism

During eclosion, cerambycid larvae rupture the egg chorion with the use of cephalic, thoracic, or abdominal spines (so-called egg burster spines) or with their mandibles (Duffy 1949, 1953; Linsley 1961; Gardiner 1966). After eclosion, most cerambycid larvae quickly tunnel into the host tissues or soil where they feed and develop over the next several months to years. As a result of these long generation times and the extensive feeding that usually occurs within the host plant, the larval stage of cerambycids is by far the most injurious life stage to the host plant. Cerambycid larvae generally are elongate and subcylindrical, with protracted mouthparts and poorly developed thoracic legs. However, some lepturine larvae have well-developed thoracic legs. For example, larvae of the European lepturine *Dinoptera collaris* (L.) are very mobile, live under loose bark and in insect galleries where they feed on frass of other borers, and can walk over the soil among logs and stumps (Duffy 1953; Bílý and Mehl 1989). Similarly, larvae of the *Quercus*-infesting lepturine *Leptura pacifica* (Linsley) have been reported to feed on frass of other cerambycids (Skiles et al. 1978).

Cerambycid larval galleries tend to be oval in cross-section with a meandering configuration when tunneling occurs in the cambial region but usually are round in cross-section and straighter when tunneling occurs in wood (Craighead 1923; Duffy 1953). The frass of cerambycid larvae, especially when feeding in woody tissue, often is granular with coarsely shredded or fibrous pieces of wood present (Hay 1968; Solomon 1977). The granular portion of the frass is material that passed through the digestive tract of the larva, whereas the shreds of wood are pieces torn off by the larva's mouthparts but not consumed (Craighead 1923; Solomon 1977).

Usually one to three years are required for most cerambycids to complete a single generation. However, some cerambycids apparently are able to complete two generations (bivoltine) per year (Matsumoto et al. 2000; Pershing and Linit 1986; Watari et al. 2002; Logarzo and Gandolfo 2005) or perhaps even three or more (multivoltine). For example, in southern China, Lu et al. (2011) demonstrated that the lamiine *G. cantor* can complete a generation in about 70 days or five generations per year. Similarly, Swezey (1950), working in Hawaii, reared adults of four cerambycids species within four months after live branches of a breadfruit tree [*Artocarpus altilis* (Parkinson) Fosberg] were cut and allowed to undergo

TABLE 2.1

Summary Data for Egg Development Time under Field or Laboratory Conditions for Selected Cerambycids

Species	Subfamily ^a	Study Location	Host Genera in Study	Study Conditions	Egg Hatch (Days)		References
					Mean	Range	
<i>Aeolesthes holosericea</i> Fabricius	Cer	India	Hardwoods	Field	–	7–12	Khan and Khan 1942
<i>Alcidion cereicola</i> Fisher	Lam	Argentina	<i>Harrisia</i>	Field	–	5–9	McFadyen and Fidalgo 1976
<i>Anoplophora chinensis</i> (Forster)	Lam	Japan	<i>Citrus</i>	20°C	14	–	Adachi 1994
				25°C	10	–	
				30°C	8	–	
<i>Anoplophora glabripennis</i> (Motschulsky)	Lam	USA	<i>Acer</i>	15°C	54	37–84	Keena 2006
				20°C	25	16–59	
				25°C	15	8–38	
				30°C	13	8–27	
<i>Apriona germari</i> Hope	Lam	India	<i>Morus</i>	Field	–	22–24	Hussain and Buhroo 2012 Yoon and Mah 1999
				25°C	18	–	
<i>Calchaenesthes pistacivora</i> Holzschuh	Cer	Iran	<i>Pistacia</i>	Field	–	10–14	Rad 2006
<i>Chion cinctus</i> (Drury)	Lam	USA	<i>Carya</i>	Field	–	7–9	Hovey 1941
<i>Colobothea distincta</i> Pascoe	Lam	Costa Rica	<i>Theobroma</i>	Field	–	8–12	Lara and Shenefelt 1966
<i>Dectes texanus</i> LeConte	Lam	USA	<i>Glycine</i>	27°C	4	3–5	Hatchett et al. 1973
<i>Eupromus ruber</i> (Dalman)	Lam	Japan	<i>Persea</i>	Field	–	7–10	Banno and Yamagami 1991
<i>Megacyllene mellyi</i> (Chevrolat)	Cer	Brazil	<i>Baccharis</i>	Field	14	–	McFadyen 1983
<i>Megacyllene robiniae</i> (Forster)	Cer	USA	<i>Robinia</i>	27°C	7	4–11	Wollerman et al. 1969
<i>Monochamus carolinensis</i> (Olivier)	Lam	USA	<i>Pinus</i>	18°C	14	–	Pershing and Linit 1986
				26°C	6	–	
				34°C	4	–	
<i>Neoptychodes trilineatus</i> (L.)	Lam	USA	<i>Ficus</i>	Field	6	3–8	Horton 1917
<i>Nealcidion deletum</i> (Bates)	Lam	Guyana	<i>Solanum</i>	Field	–	3–7	Cleare 1931
<i>Oberea schaumii</i> LeConte	Lam	USA	<i>Populus</i>	Field	–	14–15	Nord et al. 1972
<i>Oemona hirta</i> (F.)	Cer	New Zealand	<i>Citrus</i>	23°C	9	–	Wang et al. 1998

(Continued)

TABLE 2.1 (Continued)

Summary Data for Egg Development Time under Field or Laboratory Conditions for Selected Cerambycids

Species	Subfamily ^a	Study Location	Host Genera in Study	Study Conditions	Egg Hatch (Days)		References
					Mean	Range	
<i>Osphranteria coerulescens</i> Redtenbacher	Cer	Iran	<i>Prunus</i>	30°C	9	7–11	Sharifi et al. 1970
<i>Phoracantha semipunctata</i> (F.)	Cer	USA	<i>Eucalyptus</i>	20°C	5	–	Hanks et al. 1993
<i>Phoracantha semipunctata</i>	Cer	Tunisia	<i>Eucalyptus</i>	26°C	–	6–7	Chararas 1969
<i>Phytoecia rufiventris</i> Gautier	Lam	Japan	<i>Chrysanthemum</i>	20°C	10	–	Shintani 2011
				25°C	5	–	
				30°C	4	–	
<i>Prionoplus reticularis</i> White	Prio	New Zealand	<i>Pinus</i>	Field	–	16–25	Rogers et al. 2002
<i>Prionus laticollis</i> (Drury)	Prio	USA	<i>Malus</i>	27°C	19	–	Farrar and Kerr 1968
				16°C	55	–	
<i>Saperda populnea</i> (L.)	Lam	Turkey	<i>Populus</i>	Field	–	11–14	Tozlu et al. 2010
<i>Saperda populnea</i>	Lam	Korea	<i>Populus</i>	25°C	–	8–11	Park and Paik 1986
<i>Semanotus litigiosus</i> (Casey)	Cer	USA	<i>Abies</i>	Field	–	10–30	Wickman 1968
<i>Stromatium longicorne</i> (Newman)	Cer	China	Hardwoods	Field	–	10–15	Shi et al. 1982
<i>Stromatium longicorne</i>	Cer	Japan	Hardwoods	Field	–	8–12	Yashiro 1940
<i>Xylotrechus colonus</i> (Fab.)	Cer	Canada	<i>Betula</i>	Field	21	–	Gardiner 1960
<i>Xylotrechus quadripes</i> Chev.	Cer	India	<i>Coffea</i>	Field	–	5–6	Seetharama et al. 2005
<i>Xylotrechus quadripes</i>	Cer	Thailand	<i>Coffea</i>	29–31°C	5	3–9	Visitpanich 1994

^a Cer = Cerambycinae, Lam = Lamiinae, Prio = Prioninae.

natural infestation for two months before being caged. In the tropical climate of Zambia, Löyttyniemi (1983) reported that *P. semipunctata*, an introduced cerambycine pest of eucalypts, could complete two to three generations per year. In Southern California, however, Bybee et al. (2004b) found that *P. semipunctata* generally is univoltine, but that *P. recurva* Newman could complete one and a partial second generation each year. Bybee et al. (2004b) suggested that this difference in generation time may partially explain how *P. recurva* is displacing *P. semipunctata* in California even though *P. semipunctata* was first reported in California in 1984 and *P. recurva* not until 1995. However, Luhring et al. (2004) suggested that differential susceptibility to natural enemies may also be an important factor leading to *P. recurva*'s displacement of *P. semipunctata*. In the case of the spondyliid *Tetropium gabrieli* Weise, Duffy (1953) presented data showing that this beetle usually completes one generation per year in the United Kingdom, but two generations can be completed there during very warm summers. By contrast, larval development can be greatly protracted in dry wood such as flooring, molding, and furniture (Duffy 1953; Hickin 1975). For example, an adult beetle of the cerambycine *Eburia quadrigeminata* (Say) emerged from a bookcase that was constructed more than 40 years earlier (Jaques 1918).

2.5 Pupal Development and Adult Emergence

Typically, pupation occurs at the end of the larval feeding galleries between the bark and wood; within the bark, sapwood, or heartwood of woody plants; inside the stems or roots of herbaceous plants; or in the soil (Craighead 1923; Duffy 1953). There are two general types of pupal chambers that are commonly referred to as cells and cocoons. Cells are chambers constructed near the terminal end of the larval gallery in which the pupa is in direct contact with the host tissues (Figure 2.6), while cocoons are chambers formed in the soil or in wood in which larvae first line the inner walls with a calcareous or gum-like secretion produced by the larvae (Duffy 1953; Linsley 1961; Figure 2.7). Many larvae do not pack their gallery with frass as they tunnel will isolate themselves in the gallery prior to pupation by plugging



FIGURE 2.6 Pupa of the lamiine *Anoplophora glabripennis* within the pupal chamber constructed at the end of the larval gallery in *Acer* in the eastern United States. Note how the larva plugged the gallery with wood shavings prior to pupating. (Courtesy of Melody Keena [Bugwood image 5431706].)



FIGURE 2.7 Larva of the prionine *Prionus coriarius* (Linnaeus) in an earthen cocoon that it constructed in the soil in which to pupate. (Courtesy of Gyorgy Csoka, photo taken in Hungary [Bugwood image 1231074].)

the gallery with a wad of shredded plant tissue (Craighead 1923). Depending on the species and where pupation occurs within the gallery, larvae will plug one or both sides of the gallery around themselves (Linsley 1961). These wads of plant tissue are thought to provide limited protection against natural enemies and possibly aid in regulating humidity (Duffy 1953). Many larvae extend their galleries to near the outer surface of the host plant and then return deeper within the gallery to pupate and, in so doing, reduce the amount of tunneling required to exit the host after they transform into adults (Linsley 1961).

The following discussion on the types of pupation cells and cocoons constructed by cerambycid larvae is based primarily on Craighead (1923), Duffy (1953), and Linsley (1961). Some species of *Cyrtinus*, *Leiopus*, *Poecilium*, and *Rhagium* construct shallow elliptical cells between the bark and wood, often plugging the galleries with wood fibers or surrounding the cell with shredded wood. For species that commonly pupate in the bark, they will instead pupate in wood if the bark is relatively thin or has fallen away. Several species that pupate in wood (e.g., species of *Aeolesthes*, *Aromia*, *Callidium*, *Cerambyx*, *Enaphalodes*, *Molorchus*, and *Saperda*) turn around at the end of the gallery prior to pupation so that once transformed the new adult can use the same gallery to exit, and moreover, several of these species (especially Cerambycini) plug the gallery entrance with a calcareous secretion prior to pupation. In others (e.g., *Apriona*, *Goes*, and *Monochamus*), the larvae construct pupation cells at the end of their galleries near the outer sapwood but do not turn; thus, the new adults must extend the gallery to exit the host. In many cerambycids that tunnel in the stems of herbaceous plants and small-diameter woody stems and twigs (e.g., *Agapanthia*, *Oberea*, and *Phytoecia*), the larvae plug one or both ends of the gallery around themselves with shredded plant tissue, and later, after pupating, the new adults chew through the wall of the stem or twig to exit. Many root-feeding cerambycids as well as some wood-feeding lepturines that exit their host and fall to the ground to pupate prepare earthen cocoons in the soil for pupation by hollowing out a chamber and often cementing the inner soil particles with a secretion produced by larvae (e.g., *Acmaeops*, *Anthophylax*, *Gaurotes*, *Judolia*, *Pachyta*, *Prionus*, and *Tetraopes*). Some cerambycids (e.g., *Plocaederus* and *Xystrocera*) construct calcareous cocoons in wood by coating the inner walls of the chamber with a calcium carbonate solution that is regurgitated by the larvae.

Prior to pupation, cerambycid larvae stop feeding, become quiescent, and contract in body length (Duffy 1953). Most cerambycids are oriented head-up for those that pupate within the host plant or

horizontal for those that pupate in the soil (Duffy 1953). When pupation occurs within the host plant, stout spines usually are present on the abdominal tergites of the pupa, and these structures likely aid in anchoring the pupa within the gallery (Duffy 1953). Such spines are lacking in species that pupate horizontally in the soil (Craighead 1923). Although most pupae are inactive, pupae of the lamiine *Agapanthia villosoviridescens* (DeGeer) can use their spines to quickly ascend and descend within the larval gallery that is found in stems of its herbaceous hosts (Duffy 1953).

The duration of the pupal period varies considerably among cerambycids and is greatly affected by ambient temperature. Duffy (1953) stated that the pupal stage usually takes three to four weeks to complete, but some species require up to six weeks. By contrast, Linsley (1961) stated that the pupal stage lasts 7–10 days in most cases but up to a month can be required. Several examples of the time required to complete the pupal stage are presented in Table 2.2. For the field studies listed, the range of time required to complete the pupal stage varies from as little as six to eight days, in the lamiine *Nealcidion deletum* in Guyana (Cleare 1931), to 25–35 days in the cerambycine *Xylotrechus quadripes* Chevrolat in Thailand (Visitpanich 1994). In laboratory studies conducted at constant temperatures, the mean time to complete the pupal stage varies from 47 days at 15°C to 12 days at 30°C for the lamiine *A. glabripennis* (Keena and Moore 2010) and from 15 days at 22°C to 8 days at 34°C for the lamiine *M. carolinensis* (Pershing and Linit 1986). In the species where data are available (Table 2.2), males generally have a shorter pupal period than females.

After completion of the pupal stage, many physiological changes occur within newly eclosed adults, including sclerotization of the exoskeleton (Neville 1983). This process may take several days, and once complete, the new adult will initiate emergence, which often takes several more days, especially for adults that must chew through wood and bark to exit the host plant. For example, newly eclosed *A. glabripennis* adults took an average of seven days before starting to tunnel out of the wood and another five days, on average, to tunnel through the wood and emerge at 20°C and, similarly, five plus four days at 25°C and four plus four days at 30°C (Sánchez and Keena 2013). Adult cerambycids construct exit holes that are broadly oval to circular (Figure 2.8).

2.6 Overwintering, Quiescence, and Diapause

During periods of adverse environmental conditions, insects as well as invertebrates in general become dormant for varying periods of time. There are two general types of dormancy: quiescence and diapause. Quiescence is controlled exogenously (e.g., low ambient temperatures), whereas diapause is controlled endogenously (e.g., hormonal changes within the insect). For many cerambycids, the lower threshold temperature for development is about 10–12°C (Pershing and Linit 1986; Keena 2006; Naves and de Sousa 2009; Keena and Moore 2010; García-Ruiz et al. 2011). Therefore, in theory, when cerambycids experience these or lower temperatures, they would become quiescent and not develop further until the threshold temperature is again exceeded.

It appears that some cerambycids undergo true diapause although others simply become quiescent when temperatures drop below the developmental threshold. For example, while developing rearing methods for several cerambycid species, Gardiner (1970) reported that the final larval instars of the lamiine *Graphisurus fasciatus* (DeGeer) appeared to undergo true diapause and required about one month of cold treatment to break diapause. Similarly, when developing rearing methods for cerambycid pests of sunflowers, it was discovered that the lamiine *Ataxia hubbardi* Fisher undergoes facultative diapause (= quiescence), although the lamiine *Mecas cana saturnina* (LeConte) [reported as *M. inornata* Say; Linsley and Chemsak (1995)] undergoes obligatory diapause (Rogers 1977b; Rogers and Serda 1979). For some members of the lamiine genus *Monochamus*, an obligatory diapause has been reported for *M. alternatus* (Togashi 1991), *M. galloprovincialis* (Olivier) (Naves et al. 2007; Koutroumpa et al. 2008), and *M. saltuarius* (Gebler) (Togashi et al. 1994), but not for *M. carolinensis*, which can complete two generations per year (Pershing and Linit 1986).

Various combinations of temperature and photoperiod have been investigated to explore the conditions most favorable for diapause induction (Shintani et al. 1996; Asano et al. 2004) and termination (Togashi 1987, 1991; Jikumaru and Togashi 1996; Kitajima and Igarashi 1997; Esaki 2001; Rogers et al. 2002; Asano et al. 2004; Naves et al. 2007). By contrast, in southern China, where ambient temperatures

TABLE 2.2

Summary Data for Pupal Development Time under Field or Laboratory Conditions for Selected Cerambycids

Species	Subfamily ^a	Country	Host Genus	Rearing Temp. or Conditions	Pupation Time (Days)		References
					Mean	Range	
<i>Acalolepta vastator</i> (Newman)	Lam	Australia	<i>Vitis</i>	Field, male	20	–	Goodwin and Pettit 1994
				Field, female	22	–	
<i>Alcidion cereicola</i> Fisher	Lam	Argentina	<i>Harrisia</i>	Field	–	10–11	McFadyen and Fidalgo 1976
<i>Anoplophora chinensis</i>	Lam	Japan	<i>Citrus</i>	20°C	24	–	Adachi 1994
<i>Anoplophora glabripennis</i> (Motschulsky)	Lam	USA	<i>Acer</i>	15°C	47	–	Keena and Moore 2010
				20°C	26	–	
				25°C	18	–	
				30°C	12	–	
<i>Anoplophora macularia</i> (Thomson)	Lam	Taiwan	<i>Citrus</i> (diet)	25°C	–	10–26	Lee and Lo 1998
<i>Apriona germari</i> Hope	Lam	India	<i>Morus</i>	Field	28	–	Hussain and Buhroo 2012
				25°C, male	18	–	Yoon and Mah 1999
				25°C, female	19	–	
<i>Calchaenesthes pistacivora</i> Holzschuh	Cer	Iran	<i>Pistacia</i>	Field	45	–	Rad 2006
<i>Dectes texanus</i> LeConte	Lam	USA	<i>Glycine</i>	27°C	10	7–15	Hatchett et al. 1973
<i>Megacyllene robiniae</i> (Forster)	Cer	USA	<i>Robinia</i>	27°C	13	5–17	Wollerman et al. 1969
				27°C, male	11	7–14	Galford 1984
				27°C, female	12	8–15	
<i>Monochamus carolinensis</i> (Olivier)	Lam	USA	<i>Pinus</i>	22°C	15	–	Pershing and Linit 1986
				26°C	9	–	
				34°C	8	–	
<i>Nealcidion deletum</i> (Bates)	Lam	Guyana	<i>Solanum</i>	Field	–	6–8	Cleare 1931
<i>Neoptychodes trilineatus</i> (L.)	Lam	USA	<i>Ficus</i>	Field	24	5–73	Horton 1917

(Continued)

TABLE 2.2 (Continued)

Summary Data for Pupal Development Time under Field or Laboratory Conditions for Selected Cerambycids

Species	Subfamily ^a	Country	Host Genus	Rearing Temp. or Conditions	Pupation Time (Days)		References
					Mean	Range	
<i>Oemona hirta</i> (F.)	Cer	New Zealand	<i>Populus</i>	23°C	15–19	–	Wang et al. 2002
<i>Osphranteria coerulea</i> Redtenbacher	Cer	Iran	<i>Prunus</i>	30°C	15	12–21	Sharifi et al. 1970
<i>Phytoecia rufiventris</i> Gautier	Lam	Japan	<i>Chrysanthemum</i>	20°C	22	–	Shintani 2011
				25°C	15	–	
				30°C	11	–	
<i>Prionoplus reticularis</i> White	Prio	New Zealand	<i>Pinus</i>	Field	25	20–24	Morgan 1960; Rogers et al. 2002
<i>Prionus laticollis</i> (Drury)	Prio	USA	<i>Malus</i>	18°C	25	–	Benham 1969
<i>Saperda populnea</i> (L.)	Lam	Korea	<i>Populus</i>	25°C	11	–	Park and Paik 1986
<i>Semanotus litigiosus</i> (Casey)	Cer	USA	<i>Abies</i>	Field	–	14–28	Wickman 1968
<i>Stromatium longicorne</i> (Newman)	Cer	China	Hardwoods	Field	–	15–18	Shi et al. 1982
<i>Xylotrechus arvicola</i> (Olivier)	Cer	Spain	<i>Vitis</i>	24°C, male	16	–	García-Ruiz et al. 2012
				24°C, female	18	–	
<i>Xylotrechus quadripes</i> Chevrolat	Cer	India	<i>Coffea</i>	Field	–	25–35	Seetharama et al. 2005
<i>Xylotrechus quadripes</i>	Cer	Thailand	<i>Coffea</i>	29–31°C	11	9–15	Visitpanich 1994

^a Cer = Cerambycinae, Lam = Lamiinae, Prio = Prioninae.



FIGURE 2.8 Exit hole made by an adult of the lamiine *Saperda populnea* (L.) upon emergence from its host, *Populus*. (Courtesy of Gyorgy Csoka, photo taken in Hungary [Bugwood image 1141004].)

often support insect development year-round, Lu et al. (2011) found no evidence of diapause in the multivoltine lamiine *G. cantor*.

The vast majority of cerambycids overwinter in the larval stage. For example, in field studies conducted during a U.S. eradication program for the lamiine *A. glabripennis* in Illinois, of 569 *A. glabripennis* life stages recovered during dissections of infested trees in winter and early spring, 542 individuals were live larvae (95%) and 27 appeared to be viable eggs (5%) (Haack et al. 2006). Similarly, at an *A. glabripennis* outbreak site in northeastern Italy, most individuals overwintered as mature larvae in xylem, although some apparently living eggs and young larvae were found in the phloem (Faccoli et al. 2015). Although the overwintering eggs and young larvae were likely the result of late-season oviposition, many had died—possibly reflecting lower winter temperatures in the phloem compared to the xylem and lower fat stores of young larvae compared to mature larvae (Faccoli et al. 2015). Similarly, of 78 North American tree- and shrub-infesting cerambycids for which Solomon (1995) listed the overwintering life stage, 76 overwintered as larvae, although 2 species were said to overwinter as either larvae or pupae, both being cerambycines with two-year life cycles: *Anelaphus parallelus* (Newman), a twig pruner primarily of *Quercus*, and *Xylocrius agassizi* (LeConte), a root borer on *Ribes*.

A few cerambycids have been reported to overwinter as adults. Generally, these are individuals that pupate in late summer or autumn, and the adults then remain within the pupal cell until the following spring. This behavior has been reported for some species of the cerambycine genus *Cerambyx*; the lamiine genera *Mesosa*, *Phytoecia*, and *Pogonocherus*; and the lepturine genus *Rhagium* (Duffy 1953; Linsley and Chemsak 1972; Bílý and Mehl 1989; Bense 1995). Another example is the cerambycine *Aeolesthes holosericea* Fabricius, which either pupates in late summer and then overwinters as an adult within the pupal chamber or overwinters as a larva and then pupates and emerges as an adult the following year (Gupta and Tara 2013). In addition, adults of a few cerambycids do overwinter outside their pupal cells (Linsley 1936, 1961). For example, adults of the lamiine *Psenocerus supernotatus* (Say) have been found overwintering in the outer folds of the cocoons of the large saturniid moth *Hyalophora cecropia* (L.) (Lepidoptera: Saturniidae) in Pennsylvania, in the United States (Hamilton 1884).

2.7 Dispersal

Although some cerambycids are flightless, the majority are capable of flight (Figure 2.9). Duffy (1953) states that, in the United Kingdom, most cerambycids are day flyers (diurnal), while in the tropics most fly at dusk or dawn (crepuscular) or at night (nocturnal). In general, species that are diurnal fliers are faster and more agile in flight than nocturnal fliers (Linsley 1959). Many of the nocturnal species are attracted to lights. Most cerambycids demonstrate slow, directed flight, usually in the direction of food plants, larval host plants, or potential mates. At the subfamily level, the Lamiinae and Prioninae tend to be nocturnal while the Lepturinae typically are diurnal. Adults of many Lepturinae are strong and agile flyers, which is beneficial given that these adults usually feed and mate on flowers that are different plant species than the plants used as larval hosts (Hanks 1999). Although many cerambycids are slow flyers, especially many Prioninae, the lepturine *Judolia cerambyciformis* (Schrank) can hover and fly up and down over flowers, and the necydaline *Ulochaetes leoninus* LeConte can fly like a *Bombus* bumblebee (Hymenoptera: Apidae) (Duffy 1953). Lamiine adults usually feed daily and mate, feed, and oviposit on the same host plant and therefore commonly fly between the crown foliage where they feed and the branches and stems where they oviposit (Craighead 1923; Linsley 1961; Hanks 1999).

Dispersal in the Cerambycidae has been studied primarily in species that are forest pests as well as a few rare species. These types of studies are important—especially for introduced (= alien or exotic) species where quarantine zones need to be established—and there is a need to set survey boundaries and model potential pest spread (Kobayashi 1984; Takasu et al. 2000; Smith et al. 2001; Haack et al. 2010a; Hernández et al. 2011; Akbulut and Stamps 2012; also see Chapter 13). In other studies, researchers explored various attributes of the beetles themselves that would help support longer flight as well as attributes of the hosts that would increase attraction. For example, Hanks et al. (1998) reported that, in the cerambycine *P. semipunctata*, larger individuals tended to disperse further than smaller adults. Similarly, in field studies on the cerambycine *Semanotus japonicus* Lacordaire, Ito (1999) reported that adults preferentially landed on larger-diameter trees. In another study on *S. japonicus*, Shibata (1989) predicted that the average dispersal distance would increase throughout the period of adult emergence given that ambient temperatures would be near the flight threshold early in the flight season but that later in the flight season, the air temperatures would be well above the threshold.

The distances that cerambycid adults can fly have been estimated in laboratory studies using flight mills and in field studies using mark–recapture techniques (Table 2.3). The maximum distances recorded



FIGURE 2.9 Adult beetle of the lamiine *Anoplophora glabripennis* preparing for flight. (Courtesy of Roger Zerillo, photo taken in USA.)

TABLE 2.3

Summary Data for Selected Cerambycids with Published Dispersal Information

Species	Subfamily ^a	Country	Host Plant	Study Details	Findings	References
<i>Anoplophora chinensis</i> (Forster)	Lam	Japan	<i>Citrus</i>	Mark recapture in citrus orchard	Proof of immigration into orchard	Komazaki and Sakagami 1989
<i>Anoplophora glabripennis</i> (Motschulsky)	Lam	Korea	<i>Salix</i>	Used harmonic radar for 14 days	Mean dispersal 14 m (max 92 m) in 14 days	Williams et al. 2004
<i>Anoplophora glabripennis</i>	Lam	China	<i>Populus</i>	Mark–recapture in poplar stand	Mean dispersal 42 m (max 214 m) in 19 days	Zhou et al. 1984
<i>Anoplophora glabripennis</i>	Lam	China	?	Mark–recapture	Mean dispersal of 106 m over 20–28 days	Wen et al. 1998
<i>Anoplophora glabripennis</i>	Lam	China	<i>Populus</i>	Mark–recapture	Mean dispersal 266 m (max 1442 m) in 9 wks	Smith et al. 2001
<i>Anoplophora glabripennis</i>	Lam	China	<i>Populus, Salix, Ulmus</i>	Mark–recapture, season-long study	98% of adults dispersed under 920 m; max dispersal was 2,394 m for a male and 2,644 m for a female	Smith et al. 2004
<i>Hirticlytus comosus</i> (Matsushita)	Cer	Japan	<i>Podocarpus</i>	Tethered flight in laboratory	Mean estimated flight 122 m, max = 1,170 m	Sato 2005
<i>Monochamus alternatus</i> Hope	Lam	Japan	<i>Pinus</i>	Mark recapture in young pine stand	Early season mean dispersal was 19 m for males (max 55 m) and 23 m for females (max 59 m)	Shibata 1986a
<i>Monochamus alternatus</i>	Lam	Japan	<i>Pinus</i>	Circumstantial evidence	Two reports cited stating that islands 3.3 km from nearest outbreak became infested	Kobayashi et al. 1984; Togashi 1990a
<i>Monochamus carolinensis</i> (Olivier)	Lam	U.S.	<i>Pinus</i>	Flight mill study	Mean flight was 2.2 km in 2 hr; max = 10.3 km in 115 min	Akbulut and Linit 1999

(Continued)

TABLE 2.3 (Continued)

Summary Data for Selected Cerambycids with Published Dispersal Information

Species	Subfamily ^a	Country	Host plant	Study details	Findings	References
<i>Monochamus galloprovincialis</i> (Olivier)	Lam	France	<i>Pinus</i>	Flight mill study with adults flown once weekly, for up to 2 hr, until death	Average total distance flown was 15.6 km for males, 16.3 km for females, with a max. of 62.7 km	David et al. 2014
<i>Monochamus galloprovincialis</i>	Lam	Spain	<i>Pinus</i>	Mark recapture	One adult was captured in the most distant trap at 8.3 km	Gallego et al. 2012
<i>Monochamus galloprovincialis</i>	Lam	Spain	<i>Pinus</i>	Mark recapture	Season-long study, with several flying >3 km, and one flew 7.1 km	Hernández et al. 2011
<i>Monochamus galloprovincialis</i>	Lam	Spain	<i>Pinus</i>	Mark recapture	Some adults flew 13.6 to 22.1 km	Mas et al. 2013
<i>Phoracantha semipunctata</i> (F.)	Cer	South Africa	<i>Eucalyptus</i>	Circumstantial evidence	An isolated outbreak was 14 km from any other known source	Drinkwater 1975
<i>Phoracantha semipunctata</i>	Cer	Spain	<i>Eucalyptus</i>	Circumstantial evidence	Two isolated outbreaks were about 2 and 5 km from any known source	Martinez Egea 1982
<i>Rosalia alpina</i> (L.)	Cer	Czech Republic	<i>Fagus</i>	Mark recapture	Furthest dispersal detected: 1.6 km in 11 days	Drag et al. 2011
<i>Semanotus japonicas</i> Lacordaire	Cer	Japan	<i>Cryptomeria</i>	Mark recapture	Seasonal mean dispersal was 9 m for males (max 80 m) and 16 m for females (max 150 m)	Shibata 1986b
<i>Tetraopes tetrophthalmus</i> (Forster)	Lam	USA	<i>Asclepias</i>	Mark recapture	Average dispersal over 10 days was less than 40 m	McCauley et al. 1981

^a Cer = Cerambycinae, Lam = Lamiinae.

in field studies can be influenced by the number of insects released, the number of traps deployed, the trapping distances used, and the length of time over which the study is conducted. Some of the extreme dispersal distances recorded based on mark–recapture studies were 2.6 km for the lamiine *A. glabripennis* (Smith et al. 2004) and 22.1 km for the lamiine *M. galloprovincialis* (Mas et al. 2013). For the flight-mill studies, the estimated maximum distances flown were 1.2 km for the cerambycine *Hirticlytus comosus* (Matsushita) (Sato 2005), 10.3 km for *M. carolinensis* (Akbulut and Linit 1999), and 62.7 km for *M. galloprovincialis* (David et al. 2014).

There are also several estimates of cerambycid dispersal based on circumstantial evidence (Table 2.3). For example, in Japan, *Pinus* trees infected with pine wilt disease, which is caused by an exotic xylem-invading nematode that is vectored by *M. alternatus* adults, were found on isolated islands that were approximately 3.3 km from the nearest disease centers. Therefore, *M. alternatus* adults were assumed to have flown that distance over water and carried the nematodes (Kobayashi et al. 1984; Togashi 1990a). Similarly, based on the nearest known outbreaks to newly discovered infestations, cerambycine *P. semipunctata* adults were assumed to have dispersed at least 5 km at a site in Spain (Martínez Egea 1982) and 14 km in South Africa (Drinkwater 1975). In Nova Scotia, Canada, where the European spondylidine *Tetropium fuscum* (F.) was introduced around 1990, new infestations have extended about 80 km from the original site of introduction after 20 years of spread (Rhainds et al. 2011).

Dispersal has also been studied in a few flightless cerambycids, such as the European lamiine *Dorcadion fuliginator* (L.), an endangered grass-feeding species (Baur et al. 2005). At a study site in Central Europe where several isolated grassland patches were surrounded by agricultural fields and human settlements, several beetles were observed to move 20–100 m, with one male moving a maximum of 218 m in 12 days. Similarly, the cactus-feeding lamiine *Moneilema* species, which are native to western North America, are also flightless, and several species occur in isolated patches along mountain slopes and therefore would likely have restricted capacity for dispersal (Lingafelter 2003; Smith and Farrell 2005).

In addition to natural dispersal, several cerambycids have been moved outside their native range as a result of inadvertent, human-assisted transport, including trade or movement of live plants, solid wood packaging materials, and firewood (Haack 2006; Cocquempot and Lindelöw 2010; Haack et al. 2010a, 2010b; Hu et al. 2013; Haack et al. 2014; Rassati et al. 2016; also see Chapter 13). For example, *A. chinensis* (Forster) has been moved primarily from its native range in Asia to other countries in live trees, including both nursery stock and bonsai plants, while *A. glabripennis* has been moved primarily in wood packaging materials such as pallets and crating (Haack et al. 2010a). During inspections of wood packaging materials entering U.S. ports of entry, cerambycids were second only to scolytines in being the most common group of wood borers encountered, representing about 20–25% of wood borers intercepted (Haack 2006; Haack et al. 2014). Moreover, during a survey conducted in Michigan of firewood transported in vehicles by the public, live bark- and wood-infesting insects were found in 23% of the individual firewood pieces, with most of the live borers encountered being cerambycids (Haack et al. 2010b).

2.8 Adult Longevity

Duffy (1953) and Linsley (1959) reported that cerambycid adults generally live from several days to several months, with females usually living longer than males in any given species. Longevity likely is linked to adult feeding habits and, given that adults of some subfamilies seldom feed (e.g., Prioninae) while others feed almost daily (e.g., Lamiinae and Lepturinae), it would not be surprising that on average the prionines would tend to have shorter adult life spans than the lamiines and lepturines. Nevertheless, Craighead (1923) reported that some prionine adults have been kept in captivity for 30–40 days without feeding. By contrast, Beeson and Bhatia (1939) reported that adults of the lamiine *Batocera rufomaculata* (De Geer) can live up to eight months. Duffy (1953) suggested that some of the longest-lived adults would likely be those that pupate in late summer, eclose, and then overwinter as adults within their pupal cells and thereby be in the adult stage for at least seven months. As mentioned in the earlier overwintering

discussion (Section 2.6), these species would include cerambycines (*Cerambyx*), lamiines (*Mesosa*, *Phytoecia*, and *Pogonocherus*), and lepturines (*Rhagium*).

Longevity data from field and laboratory studies for a number of cerambycids are presented in Table 2.4. Mean longevity values varied from about one to four months in the field studies and from less than one month to more than seven months in the laboratory studies. The greatest mean values (more than 200 days) were reported for the cerambycine *P. recurva* at 20°C (Bybee et al. 2004a) and the lamiine *M. alternatus* at 28°C (Zhang and Linit 1998; Table 2.4).

Adult longevity can be significantly impacted by the ambient temperature as well as by larval and adult food sources (Table 2.4). For example, Keena (2006) reported that longevity for the lamiine *A. glabripennis* peaked at 10°C and declined at lower and higher temperatures, while Smith et al. (2002) found that *A. glabripennis* adults lived longer when fed on *Acer* twigs compared with *Salix* twigs. In the case of the lamiine *M. galloprovincialis*, Akbulut et al. (2007) reported that adults lived longer when (as larvae) they developed in logs that were cut in spring or fall as compared with logs cut in summer, possibly reflecting seasonal variation in wood moisture content.

2.9 Population Dynamics in Relation to Environmental Conditions

Many factors can affect the population dynamics of bark- and wood-infesting insects, such as availability and susceptibility of host plants, intra- and interspecific competition, parasitization, predation, and climatic factors such as temperature and rainfall (Coulson 1979). As detailed by Hanks (1999), cerambycids often are very selective about the condition of the host plant chosen for oviposition, with some favoring apparently healthy hosts, others weakened or severely stressed hosts, and still others hosts that are dead. There are many physical and environmental stressors that can affect individual plants and move the individual plants along a continuum from healthy to stressed to dead. Some of the physical factors that can weaken a plant include soil nutrient levels, soil pH, and soil compaction. Similarly, some of the environmental stressors that alter plant resistance to insects include air pollution (Alstad et al. 1982), defoliation (Kulman 1971), drought (Mattson and Haack 1987; Wallner 1987), fire (McCullough et al. 1998), and ice and wind damage (Gandhi et al. 2007; Schowalter 2012). Besides lowering a tree's resistance to insect infestation, environmental stressors can interact in complicated ways to affect not only the host plant but also the herbivore and the herbivore's natural enemies. In the case of drought, for example, Mattson and Haack (1987) contend that drought-stressed plants are more attractive and more susceptible to colonizing herbivores; the plant tissues of stressed plants are nutritionally superior; and the elevated plant and ambient temperatures during drought favor herbivores over their natural enemies as well as favor the herbivore's detoxification system, immune system, and symbiotic microorganisms.

In life-table studies of various cerambycids, the highest levels of mortality usually occurred during the larval stage—often the early larval stages. This relationship has been reported for the cerambycines *P. semipunctata* (Powell 1982) and *Styloxus bicolor* (Champlain & Knoll) (Itami and Craig 1989) as well as for the lamiines *A. glabripennis* (Zhao et al. 1993), *M. galloprovincialis* (Koutroumpa et al. 2008), *Oberea schaumii* LeConte (Grimble and Knight 1971), and *Saperda inornata* Say (Grimble and Knight 1970). Although most researchers reported that mortality usually was highest among early larval instars, Rogers (1977a) reported that most mortality in the twig-girdling lamiine *O. cingulata* occurred in the egg stage, whereas Togashi (1990b) reported that the highest mortality for *M. alternatus* occurred among late larval instars, often when they were in their pupal cells, and that insect predators were the leading mortality agents. Similarly, in studies on the cerambycine *E. rufulus*, which has a two-year life cycle, Haavik et al. (2012) reported that the highest mortality occurs in the second summer of larval development when larvae tunnel from the cambial region into the sapwood. Researchers have also reported that larval survivorship increases with log diameter (Akbulut et al. 2004; Koutroumpa et al. 2008) and that the first larva to colonize a particular area of a log tends to have a higher probability of surviving encounters with other larvae that are tunneling nearby, especially when the neighboring larva is younger (Anbutsu and Togashi 1997). For twig- and branch-infesting cerambycids, premature branch breakage and subsequent early drying of the host tissues can lead to high larval mortality (Itami and Craig 1989). Shibata (2000)

TABLE 2.4

Summary Data for Adult Longevity under Field or Laboratory Conditions for Selected Cerambycids

Species	Subfamily ^a	Country	Hosts Genera in Study	Study Details	Longevity (Days)		References
					Mean	Range	
<i>Acalolepta vastator</i> (Newman)	Lam	Australia	<i>Vitis</i>	Field, male	42	20–103	Goodwin and Pettit 1994
				Female	47	22–131	
<i>Anoplophora chinensis</i>	Lam	Japan	<i>Citrus</i>	Females caged at ambient conditions	78	47–109	Adachi 1988
<i>Anoplophora glabripennis</i> (Motschulsky)	Lam	USA	<i>Acer</i>	25°C, male	99–106	–	Keena 2002
				Female	73–88	–	
<i>Anoplophora glabripennis</i>	Lam	USA	<i>Acer, Salix</i>	22–25°C, adult food			Smith et al. 2002
				<i>Acer platanoides</i>	104	44–131	
				<i>Acer rubrum</i>	97	30–137	
				<i>Salix nigra</i>	83	58–107	
<i>Anoplophora glabripennis</i>	Lam	USA	<i>Acer</i>	–1°C (♂, ♀)	19, 21	–	Keena 2006
				5°C (♂, ♀)	42, 44	–	
				10°C (♂, ♀)	145, 136	–	
				15°C (♂, ♀)	102, 76	–	
				20°C (♂, ♀)	128, 85	–	
				25°C (♂, ♀)	98, 79	–	
				30°C (♂, ♀)	57, 56	–	
				35°C (♂, ♀)	19, 21	–	
<i>Apriona garmari</i> Hope	Lam	Korea	<i>Morus</i>	25°C (♂, ♀)	44, 41	–	Yoon and Mah 1999
<i>Ataxia hubbardi</i> Fisher	Lam	USA	<i>Glycine</i>	26°C (♂, ♀)	87, 67	–	Rogers and Serda 1979
<i>Callidiellum rufipenne</i> (Motschulsky)	Cer	Japan	<i>Cryptomeria</i>	Ambient (♂, ♀)	18, 17	–	Shibata 1994
<i>Enaphalodes rufulus</i> (Haldeman)	Cer	USA	<i>Quercus</i>	20°C	21	–	Galford 1985
<i>Dorcadion fuliginator</i> (L.)	Lam	Border of Switzerland, Germany and France	<i>Bromus erectus</i> and others	Field mark–recapture study, longevity estimated from results	11	–	Baur et al. 2005
<i>Glenea cantor</i> (F.)	Lam	China	<i>Bombax</i>	25°C (♂, ♀)	47, 72	–	Lu et al. 2011
<i>Megacyllene robiniae</i> (Forster)	Cer	USA	<i>Robinia</i>	27°C	34	14–55	Wollerman et al. 1969
<i>Monochamus alternatus</i> Hope	Lam	USA	<i>Pinus</i>	28°C, mated	180	–	Zhang and Linit 1998
				unmated	207	–	
<i>Monochamus carolinensis</i> (Olivier)	Lam	USA	<i>Pinus</i>	28°C, mated	173	–	Zhang and Linit 1998
				unmated	103	–	

(Continued)

TABLE 2.4 (Continued)

Summary Data for Adult Longevity under Field or Laboratory Conditions for Selected Cerambycids

Species	Subfamily ^a	Country	Hosts Genera in Study	Study Details	Longevity (Days)		References
					Mean	Range	
<i>Monochamus galloprovincialis</i> (Olivier)	Lam	Turkey	<i>Pinus</i>	24–26°C, larval food	41	–	Akbulut et al. 2007
				Spring-cut logs	18	–	
				Summer-cut logs	39	–	
<i>Monochamus galloprovincialis</i>	Lam	Portugal	<i>Pinus</i>	25°C, males	61	5–128	Naves et al. 2006
				25°C, females	64	3–125	
<i>Monochamus galloprovincialis</i>	Lam	France	<i>Pinus</i>	23°C, females		75–113	Koutroumpa et al. 2008
<i>Monochamus leuconotus</i> (Pascoe)	Lam	South Africa	<i>Coffea</i>	Field, male	112	–	Schoeman et al. 1998
				Field, female	122	–	
<i>Monochamus saltuarius</i> (Gebler)	Lam	Korea	<i>Pinus</i>	23–27°C			Yoon et al. 2011
				Fed current year twigs (♂, ♀)	63, 58	–	
				Fed 1-yr-old twigs	46, 42	–	
				Fed 2-yr-old twigs	40, 36	–	
<i>Neoptychodes trilineatus</i> (L.)	Lam	USA	<i>Ficus</i>	Field	115	75–213	Horton 1917
<i>Oemona hirta</i> (F.)	Cer	New Zealand	<i>Populus</i>	Lab (♂, ♀)	30–50, 36–52	–	Wang et al. 2002
				Field (♂, ♀)	52, 33	–	
<i>Phoracantha recurva</i> Newman, <i>Phoracantha semipunctata</i> (F.)	Cer	USA	<i>Eucalyptus</i>	10°C	~60, 65 ^b	–	Bybee et al. 2004a
				15°C	~160, 130	–	
				20°C	~220, 120	–	
				25°C	~130, 100	–	
<i>Semanotus japonicus</i> Lacordaire	Cer	Japan	<i>Cryptomeria</i>	20–22°C (♀)	19–20	–	Shibata 1995
<i>Xylotrechus arvicola</i> (Olivier)	Cer	Spain	<i>Vitis</i>	24°C, larval collection site: Field	♀ 24	–	García-Ruiz et al. 2012
				Artificial diet	♀ 37	–	
<i>Xylotrechus pyrrhoderus</i> Bates	Cer	Japan	<i>Vitis</i>	25°C, males	18	–	Iwabuchi 1988
				25°C, females	20	–	
<i>Xylotrechus quadripes</i> Chevrolat	Cer	Thailand	<i>Coffea</i>	Field, male	24	7–46	Visitpanich 1994
				Field, female	29	81–53	

^a Cer = Cerambycinae, Lam = Lamiinae.^b First value is for *P. recurva*; second value is for *P. semipunctata*.

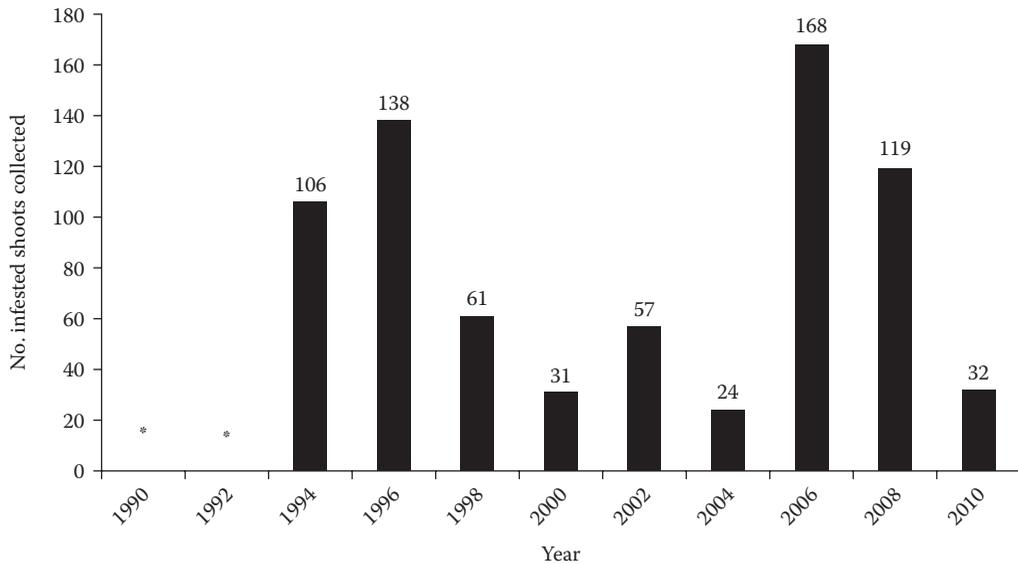


FIGURE 2.11 Number of *Anelaphus parallelus*-infested twigs collected along the same 1-km-long forest trail near Dansville, Michigan, at annual intervals from 1990 to 2011 (Haack 2012; R. A. Haack, unpublished data). Accurate counts were not made in 1990 or 1992, although newly fallen infested twigs were present in both years (signified as *). No newly fallen, infested twigs were found during any of the odd-numbered years from 1991 to 2011. *Anelaphus parallelus* has a two-year life cycle in Michigan, with twigs falling to the ground (after being partially severed by the larvae) in even-numbered years and the adults emerging from the fallen twigs in odd-numbered years.

not begin until 1994. Based on the data shown in Figure 2.11 (R. A. Haack, unpublished data), it is clear that *A. parallelus* has a two-year life cycle in Michigan and that local populations can vary widely from generation to generation as indicated by as many as 168 infested twigs being counted in 2006 to as few as 32 twigs in 2010 along the same transect.

As mentioned earlier, many species of cerambycids commonly are associated with stressed trees. Several examples of situations where cerambycids infested trees that had been impacted by air pollution, defoliation, drought, fire, ice storms, or wind storms are listed in Table 2.5. In many of these reports, bark beetles (Scolytinae) infested the same trees either before or concurrently with the cerambycids—see Zabecki (1988) for an air pollution example; Basham and Belyea (1960) and Mamaev (1990) for defoliation; Wermelinger et al. (2008) for drought; Kimmey and Furniss (1943), Gardiner (1957), Zhang et al. (1993), and Saint-Germain et al. (2004) for fire; Ryall and Smith (2001) for ice storms; and Connola et al. (1953), Gardiner (1975), and Gandhi et al. (2009) for wind storms. By contrast, in the air pollution gradient study reported by Haack (1996) in the central United States, no major *Quercus*-infesting bark beetle species were found in living *Quercus* trees infested with cerambycids in the cerambycine genus *Enaphalodes* and the lamiine genus *Goes*, both of which infest living oak (*Quercus*) trees (Solomon 1995). This was not unexpected given that there are no major tree-killing bark beetles that infest stressed oaks in North America (Solomon 1995)—unlike the situation in Europe with the oak-infesting bark beetle *Scolytus intricatus* (Ratzeburg) (Yates 1984).

2.10 Final Note

Given the thousands of cerambycid species found worldwide, it is not surprising that these insects successfully occupy a diverse array of habitats and are capable of developing within a wide assortment of plant species and their parts and tissues. Nevertheless, basic life history information, including larval host records, still is lacking for most cerambycids therefore demanding the continued study of this family of fascinating and economically important beetles.

TABLE 2.5

Examples of where Tree-Infesting Cerambycids Populations Increased after Various Stress Events that were either Natural or Induced Experimentally

Stress Event	Natural or Experimental	Country	Major Tree Genera	Major Cerambycid Genera	References
Air pollution	Natural	Poland	<i>Abies</i>	<i>Clytus, Obrium</i>	Zabecki 1988
Air pollution	Natural	USA	<i>Quercus</i>	<i>Enaphalodes, Goes</i>	Haack 1996
Air pollution	Natural	Russia	<i>Abies, Pinus</i>	<i>Monochamus</i>	Isaev et al. 1988
Defoliation	Natural	Russia	<i>Larix</i>	<i>Acanthocinus, Tetropium</i>	Mamaev 1990
Defoliation	Natural	Canada	<i>Abies</i>	<i>Monochamus, Tetropium</i>	Basham and Belyea 1960
Drought	Natural	Switzerland	<i>Pinus</i>	<i>Acanthocinus</i>	Wermelinger et al. 2008
Drought	Experimental	Mexico	<i>Prosopis</i>	<i>Oncideres</i>	Martínez et al. 2009
Drought	Experimental	USA	<i>Eucalyptus</i>	<i>Phoracantha</i>	Hanks et al. 1999
Drought	Experimental	Portugal	<i>Eucalyptus</i>	<i>Phoracantha</i>	Caldeira et al. 2002
Fire	Natural	Canada	<i>Pinus</i>	<i>Acanthocinus, Acmaeops, Asemum, Monochamus, Rhagium, Xylotrechus</i>	Gardiner 1957
Fire	Natural	USA	<i>Abies, Larix, Picea, Pinus</i>	<i>Acanthocinus, Anoplopera, Astylopsis, Callidium, Monochamus, Pogonocherus, Rhagium</i>	Parmelee 1941
Fire	Natural	USA	<i>Pinus</i>	<i>Acanthocinus, Monochamus, Rhagium, Stictoleptura</i>	Costello et al. 2011, 2013
Fire	Natural	USA	<i>Pseudotsuga</i>	<i>Arhopalus, Asemum, Ergates, Neoclytus, Xylotrechus</i>	Kimmy and Furniss 1943
Fire	Natural	Canada	<i>Picea</i>	<i>Monochamus</i>	Saint-Germain et al. 2004; Cobb et al. 2010
Fire	Natural	China	<i>Larix, Pinus</i>	<i>Monochamus</i>	Zhang et al. 1993
Ice storm	Natural	Canada	<i>Pinus</i>	<i>Acanthocinus, Monochamus, Rhagium</i>	Ryall and Smith 2001; Ryall 2003
Wind storm	Natural	USA	<i>Picea, Pinus</i>	<i>Callidium, Monochamus, Tetropium</i>	Connola et al. 1953
Wind storm	Natural	Canada	<i>Picea, Pinus</i>	<i>Monochamus, Tetropium</i>	Gardiner 1975
Wind storm	Natural	USA	<i>Pinus</i>	<i>Monochamus</i>	Gandhi et al. 2009
Wind storm	Natural	USA	<i>Pinus</i>	<i>Monochamus</i>	Webb 1909

ACKNOWLEDGMENTS

The authors thank Toby R. Petrice and Vicente Sánchez for comments on an earlier draft of this chapter and the many photographers who supplied images to the Bugwood website at the University of Georgia.

REFERENCES

- Adachi, I. 1988. Reproductive biology of the white-spotted longicorn beetle, *Anoplophora malasiaca* Thomson (Coleoptera: Cerambycidae), in citrus trees. *Applied Entomology and Zoology* 23: 256–264.
- Adachi, I. 1994. Development and life cycle of *Anoplophora malasiaca* (Thomson) (Coleoptera: Cerambycidae) on citrus trees under fluctuating and constant temperature regimes. *Applied Entomology and Zoology* 29: 485–497.
- Akbulut, S., A. Keten, I. Baysal, and B. Yuksel. 2007. The effect of log seasonality on the reproductive potential of *Monochamus galloprovincialis* Olivier (Coleoptera: Cerambycidae) reared in black pine logs under laboratory conditions. *Turkish Journal of Agriculture and Forestry* 31: 413–422.

- Akbulut, S., and M. J. Linit. 1999. Flight performance of *Monochamus carolinensis* (Coleoptera: Cerambycidae) with respect to nematode phoresis and beetle characteristics. *Environmental Entomology* 28: 1014–1020.
- Akbulut, S., and W. T. Stamps. 2012. Insect vectors of the pinewood nematode: A review of the biology and ecology of *Monochamus* species. *Forest Pathology* 42: 89–99.
- Akbulut, S., W. T. Stamps, and M. J. Linit. 2004. Population dynamics of *Monochamus carolinensis* (Col., Cerambycidae) under laboratory conditions. *Journal of Applied Entomology* 128: 17–21.
- Alstad, D. N., G. F. Edmunds, Jr., and L. H. Weinstein. 1982. Effects of air pollutants on insect populations. *Annual Review of Entomology* 27: 369–384.
- Anbutsu, H., and K. Togashi. 1997. Effects of spatio-temporal intervals between newly-hatched larvae on larval survival and development in *Monochamus alternatus* (Coleoptera: Cerambycidae). *Researches on Population Ecology* 39: 181–189.
- Asano, W., F. N. Munyiri, Y. Shintani, and Y. Ishikawa. 2004. Interactive effects of photoperiod and temperature on diapause induction and termination in the yellowspotted longicorn beetle, *Psacotha hilaris*. *Physiological Entomology* 29: 458–463.
- Banno, H., and A. Yamagami. 1991. Life cycle and larval survival rate of the redspotted longicorn beetle, *Eupromus ruber* (Dalman) (Coleoptera: Cerambycidae). *Applied Entomology and Zoology* 26: 195–204.
- Basham, J. T., and R. M. Belyea. 1960. Death and deterioration of balsam fir weakened by spruce budworm defoliation in Ontario, Part III: The deterioration of dead trees. *Forest Science* 6: 78–96.
- Baur, B., A. Coray, N. Minoretta, and S. Zschokke. 2005. Dispersal of the endangered flightless beetle *Dorcadion fuliginator* (Coleoptera: Cerambycidae) in spatially realistic landscapes. *Biological Conservation* 124: 49–61.
- Beeson, C. F. C., and B. M. Bhatia. 1939. On the biology of the Cerambycidae (Coleopt.). *Indian Forest Records (new series): Entomology* 5: 1–235.
- Benham, G. S. 1969. The pupa of *Prionus laticollis* (Coleoptera: Cerambycidae). *Annals of the Entomological Society of America* 62: 1331–1335.
- Bense, U. 1995. *Longhorn beetles: Illustrated key to the Cerambycidae and Vesperidae of Europe*. Weikersheim: Margraf Verlag.
- Bílý, S., and O. Mehl. 1989. Longhorn beetles (Coleoptera, Cerambycidae) of Fennoscandia and Denmark. *Fauna Entomologica Scandinavica* 22: 1–204.
- Blair, K. G. 1934. Cerambycidae from the Society Islands. *B. P. Bishop Museum Bulletin* 113: 127–129.
- Bleuzen, P. 1994. *The Beetles of the World, Vol. 21: Macrodontini & Prionini I*. Venette: Sciences Naturelles.
- Butovitsch, V. 1939. Zur Kenntnis der Paarung, Eiablage und Ernährung der Cerambyciden. *Entomologisk Tidskrift* 60: 206–258.
- Bybee, L. F., J. G. Millar, T. D. Paine, and K. Campbell. 2004a. Effects of temperature on fecundity and longevity of *Phoracantha recurva* and *P. semipunctata* (Coleoptera: Cerambycidae). *Environmental Entomology* 33: 138–146.
- Bybee, L. F., J. G. Millar, T. D. Paine, K. Campbell, and C. C. Hanlon. 2004b. Seasonal development of *Phoracantha recurva* and *P. semipunctata* (Coleoptera: Cerambycidae) in southern California. *Environmental Entomology* 33: 1232–1241.
- Caldeira, M. C., V. Fernández, J. Tomé, and J. S. Pereira. 2002. Positive effect of drought on longicorn borer larval survival and growth on eucalyptus trunks. *Annals of Forest Science* 59: 99–106.
- Cannon, K. F., and W. H. Robinson. 1982. An artificial diet for the laboratory rearing of the old house borer, *Hylotrupes bajulus* (Coleoptera, Cerambycidae). *Canadian Entomologist* 114: 739–742.
- Chararas, C. 1969. Biologie et écologie de *Phoracantha semipunctata* F. (Coléoptère Cerambycidae xylophage) ravageur des Eucalyptus en Tunisie, et méthodes de protection des peuplements. *Annales de l'Institut National de Recherches Forestières de Tunisie* 2: 1–37.
- Cleare, L. D. 1931. The egg-plant stem borer, *Alcidion deletum* Bates (Col. Cerambycidae). *The Agricultural Journal of British Guiana* 4: 82–90.
- Cobb, T. P., K. D. Hannam, B. E. Kishchuk, D. W. Langor, S. A. Quideauand, and J. R. Spence. 2010. Wood-feeding beetles and soil nutrient cycling in burned forests: Implications of post-fire salvage logging. *Agricultural and Forest Entomology* 12: 9–18.
- Cocquemot, C., and A. Lindelöw. 2010. Longhorn beetles (Coleoptera, Cerambycidae). *BioRisk* 4: 193–218.
- Connola, D. P., C. J. Yops, J. A. Wilcox, and D. L. Collins. 1953. Survey and control studies of beetles attacking windthrown trees in the Adirondacks. *Journal of Economic Entomology* 46: 249–254.

- Costello, S. L., W. R. Jacobi, and J. F. Negrón. 2013. Emergence of Buprestidae, Cerambycidae, and Scolytinae (Coleoptera) from mountain pine beetle-killed and fire-killed ponderosa pines in the Black Hills, South Dakota, USA. *The Coleopterists Bulletin* 67: 149–154.
- Costello, S. L., J. F. Negrón, and W. R. Jacobi. 2011. Wood-boring insect abundance in fire-injured ponderosa pine. *Agricultural and Forest Entomology* 13: 373–381.
- Coulson, R. N. 1979. Population dynamics of bark beetles. *Annual Review of Entomology* 24: 417–447.
- Craighead, F. C. 1923. North American cerambycid-larvae. *Bulletin of the Canada Department of Agriculture* 27: 1–239.
- David, G., B. Giffard, D. Piou, and H. Jactel. 2014. Dispersal capacity of *Monochamus galloprovincialis*, the European vector of the pine wood nematode, on flight mills. *Journal of Applied Entomology* 138: 566–576.
- Dodds, K. J., C. Graber, and F. M. Stephen. 2001. Facultative intraguild predation by larval Cerambycidae (Coleoptera) on bark beetle larvae (Coleoptera: Scolytidae). *Environmental Entomology* 30: 17–22.
- Dodds, K. J., C. Graber, and F. M. Stephen. 2002. Oviposition biology of *Acanthocinus nodosus* (Coleoptera: Cerambycidae) in *Pinus taeda*. *Florida Entomologist* 85: 452–457.
- Donley, D. E. 1978. Oviposition by the red oak borer, *Enaphalodes rufulus* Coleoptera: Cerambycidae. *Annals of the Entomological Society of America* 71: 496–498.
- Drag, L., D. Hauck, P. Pokluda, K. Zimmermann, and L. Cizek. 2011. Demography and dispersal ability of a threatened saproxylic beetle: A mark-recapture study of the *Rosalia* longicorn (*Rosalia alpina*). *PLoS ONE* 6(6): e21345. doi: 10.1371/journal.pone.0021345
- Drinkwater, T. W. 1975. The present pest status of eucalyptus borers *Phoracantha* spp. in South Africa. In *Proceedings of the First Congress of the Entomological Society of Southern Africa*, eds. H. J. R. Durr, J. H. Giliomee, and S. Naser, 119–129. Pretoria: Entomological Society of Southern Africa.
- Duffy, E. A. J. 1949. A contribution towards the biology of *Aromia moschata* L., the musk beetle. *Proceedings and Transactions of the South London Entomological and Natural History Society* 1947–1948: 82–110.
- Duffy, E. A. J. 1953. *A monograph of the immature stages of African timber beetles (Cerambycidae)*. London: British Museum (Natural History).
- Eisner, T., F. C. Schroeder, N. Snyder, et al. 2008. Defensive chemistry of lycid beetles and of mimetic cerambycid beetles that feed on them. *Chemoecology* 18: 109–119.
- Esaki, K. 2001. Artificial diet rearing and termination of larval diapause in the mulberry longicorn beetle, *Apriona japonica* Thomson (Coleoptera: Cerambycidae). *Japanese Journal of Applied Entomology and Zoology* 45: 149–151.
- Faccoli, M., R. Favaro, M. T. Smith, and J. Wu. 2015. Life history of the Asian longhorn beetle *Anoplophora glabripennis* (Coleoptera: Cerambycidae) in southern Europe. *Agricultural and Forest Entomology*. 17: 188–196.
- Farrar, R. J., and T. W. Kerr. 1968. A preliminary study of the life history of the broad-necked root borer in Rhode Island. *Journal of Economic Entomology* 61: 563–564.
- Forcella, F. 1982. Why twig-girdling beetles girdle twigs. *Naturwissenschaften* 69: 398–400.
- Galford, J. R. 1984. *The locust borer*. Washington, DC: U.S. Department of Agriculture, Forest Service, Forest Insect & Disease Leaflet 71.
- Galford, J. R. 1985. *Enaphalodes rufulus*. In *Handbook of Insect Rearing, Vol. 1*, eds. P. Singh, and R. F. Moore, 255–264. New York: Elsevier.
- Gallego, D., F. J. Sanchez-Garcia, H. Mas, M. T. Campo, and Y. J. L. Lencina. 2012. Estudio de la capacidad de vuelo a larga distancia de *Monochamus galloprovincialis* (Olivier 1795). (Coleoptera: Cerambycidae) en un mosaico agro-forestal. *Boletín de Sanidad Vegetal Plagas* 38: 109–123.
- Gandhi, K. J. K., D. W. Gilmore, S. A. Katovich, W. J. Mattson, J. R. Spence, and S. J. Seybold. 2007. Physical effects of weather events on the abundance and diversity of insects in North American forests. *Environmental Review* 15: 113–152.
- Gandhi, K. J. K., D. W. Gilmore, R. A. Haack, et al. 2009. Application of semiochemicals to assess the biodiversity of subcortical insects following an ecosystem disturbance in a sub-boreal forest. *Journal of Chemical Ecology* 35: 1384–1410.
- García-Ruiz, E., V. Marco, and I. Pérez-Moreno. 2011. Effects of variable and constant temperatures on the embryonic development and survival of a new grape pest, *Xylotrechus arvicola* (Coleoptera: Cerambycidae). *Environmental Entomology* 40: 939–947.

- García-Ruiz, E., V. Marco, and I. Perez-Moreno. 2012. Laboratory rearing and life history of an emerging grape pest, *Xylotrechus arvicola* (Coleoptera: Cerambycidae). *Bulletin of Entomological Research* 102: 89–96.
- Gardiner, K. M. 1957. Deterioration of firekilled pine in Ontario and the causal wood-boring beetles. *Canadian Entomologist* 89: 241–263.
- Gardiner, L. M. 1960. Descriptions of immature forms and biology of *Xylotrechus colonus* (Fab.) (Coleoptera: Cerambycidae). *Canadian Entomologist* 92: 820–825.
- Gardiner, L. M. 1966. Egg bursters and hatching in the Cerambycidae (Coleoptera). *Canadian Journal of Zoology* 44: 199–212.
- Gardiner, L. M. 1970. Rearing wood-boring beetles (Cerambycidae) on artificial diet. *Canadian Entomologist* 102: 113–117.
- Gardiner, L. M. 1975. Insect attack and value loss in wind-damaged spruce and jack pine stands in northern Ontario. *Canadian Journal of Forest Research* 5: 387–398.
- Goodwin, S., and M. A. Pettit. 1994. *Acalolepta vastator* (Newman) (Coleoptera: Cerambycidae) infesting grapevines in the Hunter Valley, New South Wales. Biology and ecology. *Journal of the Australian Entomological Society* 33: 391–397.
- Gosling, D. C. L. 1978. Observations on the biology of the oak twig pruner, *Elaphidionoides parallelus*, (Coleoptera: Cerambycidae) in Michigan. *The Great Lakes Entomologist* 11: 1–10.
- Gosling, D. C. L. 1981. Correct identity of the oak twig pruner (Coleoptera: Cerambycidae). *The Great Lakes Entomologist* 14: 179–180.
- Grimble, D. G., and F. B. Knight. 1970. Life tables and mortality factors for *Saperda inornata* (Coleoptera: Cerambycidae). *Annals of the Entomological Society of America* 63: 1309–1319.
- Grimble, D. G., and F. B. Knight. 1971. Mortality factors for *Oberea schaumii* (Coleoptera: Cerambycidae). *Annals of the Entomological Society of America* 64: 1417–1420.
- Grzymala, T. L., and K. B. Miller. 2013. Taxonomic revision and phylogenetic analysis of the genus *Elytroleptus* Dugés (Coleoptera: Cerambycidae: Cerambycinae: Trachyderini). *Zootaxa* 3659: 1–62.
- Gupta, R., and J. S. Tara. 2013. First record on the biology of *Aeolesthes holosericea* Fabricius, 1787 (Coleoptera: Cerambycidae), an important pest on apple plantations (*Malus domestica* Borkh.) in India. *Munis Entomology & Zoology* 8: 243–251.
- Haack, R. A. 1996. Patterns of forest invertebrates along an acid deposition gradient in the midwestern United States. In *Air pollution & multiple stresses, Proceedings of the IUFRO 2.05 Conference, 7–9 September 1994, Fredericton, New Brunswick*, eds. R. Cox, K. Percy, K. Jensen, and C. Simpson, 245–257. Fredericton: Canadian Forest Service.
- Haack, R. A. 2006. Exotic bark- and wood-boring Coleoptera in the United States: Recent establishments and interceptions. *Canadian Journal of Forest Research* 36: 269–288.
- Haack, R. A. 2012. Seasonality of oak twig pruner shoot fall: A long-term dog walking study. *Newsletter of the Michigan Entomological Society* 57: 24.
- Haack, R. A., L. S. Bauer, R.-T. Gao, et al. 2006. *Anoplophora glabripennis* within-tree distribution, seasonal development, and host suitability in China and Chicago. *The Great Lakes Entomologist* 39: 169–183.
- Haack, R. A., F. Hérard, J. Sun, and J. J. Turgeon. 2010a. Managing invasive populations of Asian longhorned beetle and citrus longhorned beetle: A worldwide perspective. *Annual Review of Entomology* 55: 521–546.
- Haack, R. A., T. R. Petrice, and A. C. Wiedenhoft. 2010b. Incidence of bark- and wood-boring insects in firewood: A survey at Michigan's Mackinac Bridge. *Journal of Economic Entomology* 103: 1682–1692.
- Haack, R. A., K. O. Britton, E. G. Brockerhoff, et al. 2014. Effectiveness of the international phytosanitary standard ISPM No. 15 on reducing wood borer infestation rates in wood packaging material entering the United States. *PLoS ONE* 9(5): e96611. doi: 10.1371/journal.pone.0096611
- Haavik, L. J., M. K. Fierke, and F. M. Stephen. 2010. Factors affecting suitability of *Quercus rubra* as hosts for *Enaphalodes rufulus* (Coleoptera: Cerambycidae). *Environmental Entomology* 39: 520–527.
- Haavik, L. J., D. J. Crook, M. K. Fierke, L. D. Galligan, and F. M. Stephen. 2012. Partial life tables from three generations of *Enaphalodes rufulus* (Coleoptera: Cerambycidae). *Environmental Entomology* 41: 1311–1321.
- Hamilton, J. 1884. Notes on a few species of Coleoptera which are confused in many collections, and on some introduced European species. *Canadian Entomologist* 16: 35–38.
- Hanks, L. M. 1999. Influence of the larval host plant on reproductive strategies of cerambycid beetles. *Annual Review of Entomology* 44: 483–505.

- Hanks, L. M., J. S. Mcelfresh, J. G. Millar, and T. D. Paine. 1993. *Phoracantha semipunctata* (Coleoptera: Cerambycidae), a serious pest of eucalyptus in California: Biology and laboratory-rearing procedures. *Annals of the Entomological Society of America* 86: 96–102.
- Hanks, L. M., J. G. Millar, and T. D. Paine. 1998. Dispersal of the eucalyptus longhorned borer (Coleoptera: Cerambycidae) in urban landscapes. *Environmental Entomology* 27: 1418–1424.
- Hanks, L. M., T. D. Paine, J. G. Millar, C. D. Campbell, and U. K. Schuch. 1999. Water relations of host trees and resistance to the phloem-boring beetle *Phoracantha semipunctata* F. (Coleoptera: Cerambycidae). *Oecologia* 119: 400–407.
- Hatchett, J. H., R. D. Jackson, R. M. Barry, and E. C. Houser. 1973. Rearing a weed cerambycid, *Dectes texanus*, on an artificial medium, with notes on biology. *Annals of the Entomological Society of America* 66: 519–522.
- Hay, C. J. 1968. Frass of some wood-boring insects in living oak (Coleoptera: Cerambycidae: Lepidoptera: Cossidae and Aegeriidae). *Annals of the Entomological Society of America* 61: 255–258.
- Hernández, R., A. Ortiz, V. Pérez, J. M. Gil, and G. Sánchez. 2011. *Monochamus galloprovincialis* (Olivier, 1975) (Coleoptera: Cerambycidae), comportamiento y distancias de vuelo. *Boletín de Sanidad Vegetal Plagas* 37: 79–96.
- Hickin, N. E. 1975. *The insect factor in wood decay* (3rd ed.). London: Hutchinson.
- Horton, J. R. 1917. Three-lined fig-tree borer. *Journal of Agricultural Research* 11: 371–382.
- Hosking, G. P., and J. Bain. 1977. *Arhopalus fesus* (Coleoptera: Cerambycidae): Its biology in New Zealand. *New Zealand Journal of Forestry Science* 7: 3–15.
- Hovey, C. L. 1941. Studies on *Chion cinctus* (Drury) (Coleoptera, Cerambycidae) in Oklahoma. *Proceedings of the Oklahoma Academy of Science* 21: 23–24.
- Hu, S.-J., T. Ning, D.-Y. Fu, et al. 2013. Dispersal of the Japanese pine sawyer, *Monochamus alternatus* (Coleoptera: Cerambycidae), in mainland China as inferred from molecular data and associations to indices of human activity. *PLoS ONE* 8(2): e57568. doi: 10.1371/journal.pone.0057568
- Hussain, A., and A. A. Buhroo. 2012. On the biology of *Apriona germari* Hope (Coleoptera: Cerambycidae) infesting mulberry plants in Jammu and Kashmir, India. *Nature and Science* 10: 24–35.
- Isaev, A. S., A. S. Rozhkov, and V. V. Kiselev. 1988. *Fir sawyer beetle Monochamus urussovi* (Fisch.). Novosibirsk: Nauka Publishing House.
- Itami, J. K., and T. P. Craig. 1989. Life History of *Styloxus bicolor* (Coleoptera: Cerambycidae) on *Juniperus monosperma* in northern Arizona. *Annals of the Entomological Society of America* 82: 582–587.
- Ito, K. 1999. Differential host residence of adult cryptomeria bark borer, *Semanotus japonicus* Lacordaire (Coleoptera: Cerambycidae), in relation to tree size of Japanese cedar, *Cryptomeria japonica* D. Don. *Journal of Forest Research* 4: 151–156.
- Ito, K., and K. Kobayashi. 1991. An outbreak of the cryptomeria bark borer, *Semanotus japonicus* Lacordaire (Coleoptera: Cerambycidae) in a young Japanese cedar (*Cryptomeria japonica* D. Don) plantation. I. Annual fluctuations in adult population size and impact on host trees. *Applied Entomology and Zoology* 26: 63–70.
- Iwabuchi, K. 1988. Mating behavior of *Xylotrechus pyrrhoderus* Bates (Coleoptera: Cerambycidae). IV. Mating frequency, fecundity, fertility and longevity. *Applied Entomology and Zoology* 23: 127–134.
- Jaques, H. E. 1918. A long-lived woodboring beetle. *Proceedings of the Iowa Academy of Science* 25: 175.
- Jikumaru, S., and K. Togashi. 1996. Effect of temperature on the post-diapause development of *Monochamus saltuarius* (Gebler) (Coleoptera: Cerambycidae). *Applied Entomology and Zoology* 31: 145–148.
- Keena, M. A. 2002. *Anoplophora glabripennis* (Coleoptera: Cerambycidae) fecundity and longevity under laboratory conditions: Comparison of populations from New York and Illinois on *Acer saccharum*. *Environmental Entomology* 31: 490–498.
- Keena, M. A. 2006. Effects of temperature on *Anoplophora glabripennis* (Coleoptera: Cerambycidae) adult survival, reproduction, and egg hatch. *Environmental Entomology* 35: 912–921.
- Keena, M. A., and P. M. Moore. 2010. Effects of temperature on *Anoplophora glabripennis* (Coleoptera: Cerambycidae) larvae and pupae. *Environmental Entomology* 39: 1323–1335.
- Khan, A. R., and A. W. Khan. 1942. Bionomics and control of *Aeolesthes holosericea* F. (Cerambycidae: Coleoptera). *Proceedings of the Indian Academy of Sciences, Section B* 15: 181–185.
- Kimmey, J. W., and R. L. Furniss. 1943. *Deterioration of fire-killed Douglas-fir*. Washington, DC: U.S. Department of Agriculture Technical Bulletin 851.

- Kitajima, H., and M. Igarashi. 1997. Rearing of the cryptomeria bark borer, *Semanotus japonicas* (Coleoptera: Cerambycidae) larvae on bolts of the Japanese cedar, *Cryptomeria japonica* and termination of adult diapause by the low temperature treatments. *Journal of the Japanese Forestry Society* 79: 186–190.
- Kobayashi, F., A. Yamane, and T. Ikeda. 1984. The Japanese pine sawyer beetle as the vector of pine wilt disease. *Annual Review of Entomology* 29: 115–135.
- Komazaki, S., and Y. Sakagami. 1989. Capture-recapture study on the adult population of the white spotted longicorn beetle, *Anoplophora malasiaca* (Thomson) (Coleoptera: Cerambycidae), in a citrus orchard. *Applied Entomology and Zoology* 24: 78–84.
- Koutroumpa, F. A., B. Vincent, G. Roux-Morabito, C. Martin, and F. Lieutier. 2008. Fecundity and larval development of *Monochamus galloprovincialis*. *Annals of Forest Science* 65: 707. doi: 10.1051/forest:2008056
- Kulman, H. M. 1971. Effects of insect defoliation on growth and mortality of trees. *Annual Review of Entomology* 16: 289–324.
- Lara, E. F., and R. D. Shenefelt. 1966. *Colobothea distincta* (Coleoptera: Cerambycidae) on cacao: Notes on its morphology and biology. *Annals of the Entomological Society of America* 59: 453–458.
- Lee, C. Y., and K. C. Lo. 1998. Rearing of *Anoplophora macularia* (Thomson) (Coleoptera: Cerambycidae) on artificial diets. *Applied Entomology and Zoology* 33: 105–109.
- Lingafelter, S. W. 2003. New host and elevation records for *Moneilema appressum* LeConte (Coleoptera: Cerambycidae: Lamiinae). *Journal of the New York Entomological Society* 111: 57–60.
- Linsley, E. G. 1936. Hibernation in the Cerambycidae. *Pan-Pacific Entomologist* 12: 119.
- Linsley, E. G. 1959. Ecology of Cerambycidae. *Annual Review of Entomology* 4: 99–138.
- Linsley, E. G. 1961. The Cerambycidae of North America. Part I: Introduction. *University of California Publications in Entomology* 18: 1–135.
- Linsley, E. G., and J. A. Chemsak. 1972. Cerambycidae of North America. Part VI, No. 1: Taxonomy and classification of the subfamily Lepturinae. *University of California Publications in Entomology* 69: 1–138.
- Linsley, E. G., and J. A. Chemsak. 1995. The Cerambycidae of North America. Part VII, No. 2: Taxonomy and classification of the subfamily Lamiinae, tribes Acanthocinini through Hemilophini. *University of California Publications in Entomology* 114: 1–292.
- Logarzo, G. A., and D. E. Gandolfo. 2005. Análisis de voltinismo y la diapausa en poblaciones de *Apagomerella versicolor* (Coleoptera: Cerambycidae) en el gradiente latitudinal de su distribución en la Argentina. *Revista de la Sociedad Entomológica Argentina* 64: 143–146.
- Löyttyniemi, K. 1983. Flight pattern and voltinism of *Phoracantha* beetles (Coleoptera: Cerambycidae) in a semihumid tropical climate in Zambia. *Annales Entomologici Fennici* 49: 49–53.
- Lu, W., Q. Wang, M.-Y. Tian, J. Xu, and A.-Z. Qin. 2011. Phenology and laboratory rearing procedures of an Asian longicorn beetle, *Glenea cantor* (Coleoptera: Cerambycidae: Lamiinae). *Journal of Economic Entomology* 104: 509–516.
- Lu, W., Q. Wang, M.-Y. Tian, et al. 2013. Reproductive traits of *Glenea cantor* (Coleoptera: Cerambycidae: Lamiinae). *Journal of Economic Entomology* 106: 215–220.
- Luhring, K. A., J. G. Millar, T. D. Paine, D. Reed, and H. Christiansen. 2004. Ovipositional preferences and progeny development of the egg parasitoid *Avetianella longoi*: Factors mediating replacement of one species by a congener in a shared habitat. *Biological Control* 30: 382–391.
- Mamaev, Y. B. 1990. [Outbreaks of stem pests in larch forests of the Tuva ASSR damaged by *Dendrolimus sibiricus*.] *Izvestiya Vysshikh Uchebnykh Zavedenii—Lesnoi Zhurnal* 2: 16–19 [in Russian].
- Martínez, A. J., J. López-Portillo, A. Eben, and J. Golubov. 2009. Cerambycid girdling and water stress modify mesquite architecture and reproduction. *Population Ecology* 51: 533–541.
- Martínez Egea, J. M. 1982. *Phoracantha semipunctata* Fab. en el suroeste español: Resumen de la campaña de colocacion de arboles cebo. *Boletín de la Estacion Central de Ecología* 11: 57–69.
- Mas, H., R. Hernandez, M. Villaroya, et al. 2013. Comportamiento de dispersión y capacidad de vuelo a larga distancia de *Monochamus galloprovincialis* (Olivier 1795). 6 Congreso forestal español. 6CFE01-393. <http://www.congresoforestal.es/actas/doc/6CFE/6CFE01-393.pdf> (accessed January 27, 2016).
- Matsumoto, K., R. S. B. Irianto, and H. Kitajima. 2000. Biology of the Japanese green-lined Albizzia longicorn, *Xystrocera globosa* (Coleoptera: Cerambycidae). *Entomological Science* 3: 33–42.
- Mattson, W. J., and R. A. Haack. 1987. The role of drought in outbreaks of plant-eating insects. *BioScience* 37: 110–118.

- McCauley, D. E., J. R. Ott, A. Stine, and S. McGrath. 1981. Limited dispersal and its effect on population structure in the milkweed beetle *Tetraopes tetraophthalmus*. *Oecologia* 51: 145–150.
- McCullough, D. G., R. A. Werner, and D. Neumann. 1998. Fire and insects in northern boreal ecosystems of North America. *Annual Review of Entomology* 43: 107–127.
- McFadyen, P. J. 1983. Host specificity and biology of *Megacyllene mellyi* [Col.: Cerambycidae] introduced into Australia for the biological control of *Baccharis halimifolia* [Compositae]. *Entomophaga* 28: 65–71.
- McFadyen, R. E., and A. P. Fidalgo. 1976. Investigations on *Alcidion cereicola* [Col.: Cerambycidae] a potential agent for the biological control of *Eriocereus martinii* [Cactaceae] in Australia. *Entomophaga* 21: 103–111.
- Morgan, F. D. 1960. The comparative biologies of certain New Zealand Cerambycidae. *New Zealand Entomologist* 2: 26–34.
- Naves, P., E. de Sousa, and J. A. Quartau. 2006. Reproductive traits of *Monochamus galloprovincialis* (Coleoptera: Cerambycidae) under laboratory conditions. *Bulletin of Entomological Research* 96: 289–294.
- Naves, P., E. de Sousa, and J. A. Quartau. 2007. Winter dormancy of the pine sawyer *Monochamus galloprovincialis* (Col., Cerambycidae) in Portugal. *Journal of Applied Entomology* 131: 669–673.
- Naves, P. M., and E. M. de Sousa. 2009. Threshold temperatures and degree-day estimates for development of post-dormancy larvae of *Monochamus galloprovincialis* (Coleoptera: Cerambycidae). *Journal of Pest Science* 82: 1–6.
- Neville, A. C. 1983. Daily cuticular growth layers and the teneral adults stage in insects: A review. *Journal of Insect Physiology* 29: 211–219.
- Niisato, T. 1996. Occurrence of an archaic Molorchine beetle (Coleoptera, Cerambycidae) in western Sichuan, southwest China. *Elytra* (Tokyo) 24: 375–381.
- Nord, J. C., D. G. Grimbale, and F. B. Knight. 1972. Biology of *Oberea schaumii* (Coleoptera: Cerambycidae) in trembling aspen, *Populus tremuloides*. *Annals of the Entomological Society of America* 65: 114–119.
- Park, K. T., and H. R. Paik. 1986. Seasonal fluctuation, reproduction, development and damaging behavior of *Compsidia populnea* L. (Coleoptera: Cerambycidae) on *Populus alba* X *glandulosa*. *Korean Journal of Plant Protection* 24: 195–201.
- Parmelee, F. T. 1941. Longhorned and flat headed borers attacking fire killed coniferous timber in Michigan. *Journal of Economic Entomology* 34: 377–380.
- Peck, S. B. 2011. The beetles of Martinique, Lesser Antilles (Insecta: Coleoptera); diversity and distributions. *Insecta Mundi* 0178: 1–57.
- Pershing, J. C., and M. J. Linit. 1986. Development and seasonal occurrence of *Monochamus carolinensis* (Coleoptera: Cerambycidae) in Missouri. *Environmental Entomology* 15: 251–253.
- Pesarini, C., and A. Sabbadini. 1997. Notes on new or poorly known species of Asian Cerambycidae (Insecta, Coleoptera) II Naturalista Valtellinese. *Atti del Museo Civico di Storia Naturale di Morbegno* 7: 95–129.
- Powell, W. 1982. Age-specific life-table data for the Eucalyptus boring beetle, *Phoracantha semipunctata* (F.) (Coleoptera: Cerambycidae), in Malawi. *Bulletin of Entomological Research* 72: 645–653.
- Rad, H. H. 2006. Study on the biology and distribution of long-horned beetles *Calchaenesthes pistacivora* n. sp. (Col.: Cerambycidae): A new pistachio and wild pistachio pest in Kerman Province. *ISHS Acta Horticulturae* 726: 425–430.
- Rassati, D., F. Lieutier, and M. Faccoli. 2016. Alien wood-boring beetles in Mediterranean regions. In *Insects and diseases of Mediterranean forest systems*, eds. T. D. Paine, and F. Lieutier, 293–327. Cham, Switzerland: Springer International Publishing.
- Rhainds, M., W. E. Mackinnon, K. B. Porter, J. D. Sweeney, and P. J. Silk. 2011. Evidence for limited spatial spread in an exotic longhorn beetle, *Tetropium fuscum* (Coleoptera: Cerambycidae). *Journal of Economic Entomology* 104: 1928–1933.
- Rice, M. E. 1995. Branch girdling by *Oncideres cingulata* (Coleoptera: Cerambycidae) and relative host quality of persimmon, hickory and elm. *Annals of the Entomological Society of America* 88: 451–455.
- Riggins, J. J., L. D. Galligan, and F. M. Stephen. 2009. Rise and fall of red oak borer (Coleoptera: Cerambycidae) in the Ozark Mountains of Arkansas, USA. *Florida Entomologist* 92: 426–433.
- Rogers, C. E. 1977a. Bionomics of *Oncideres cingulata* (Coleoptera: Cerambycidae) on mesquite. *Journal of the Kansas Entomological Society* 50: 222–228.
- Rogers, C. E. 1977b. Cerambycid pests of sunflower: Distribution and behavior in the southern plains. *Environmental Entomology* 6: 833–838.

- Rogers, C. E., and J. G. Serda. 1979. Rearing and biology of *Ataxia hubbardi* and *Mecas inornata* (Coleoptera: Cerambycidae), girdling pests of sunflower. *Journal of the Kansas Entomological Society* 52: 546–549.
- Rogers, D. J., S. E. Lewthwaite, and P. R. Dentener. 2002. Rearing huhu beetle larvae, *Prionoplus reticularis* (Coleoptera: Cerambycidae) on artificial diet. *New Zealand Journal of Zoology* 29: 303–310.
- Ryall, K. L. 2003. Response of the pine engraver beetle, *Ips pini* (Coleoptera: Scolytidae) and associated natural enemies to increased resource availability following a major ice storm disturbance. Ph.D. Thesis, University of Toronto, Toronto, Ontario, Canada.
- Ryall, K. L., and S. M. Smith. 2001. Bark and wood-boring beetle response in red pine (*Pinus resinosa* Ait.) plantations damaged by the 1998 ice storm: Preliminary observations. *Forestry Chronicle* 77: 657–660.
- Saint-Germain, M., P. Drapeau, and C. Hébert. 2004. Xylophagous insect species composition and patterns of substratum use on fire-killed black spruce in central Quebec. *Canadian Journal of Forest Research* 34: 677–685.
- Sánchez, V., and M. A. Keena. 2013. Development of the teneral adult *Anoplophora glabripennis* (Coleoptera: Cerambycidae): Time to initiate and completely bore out of maple wood. *Environmental Entomology* 42: 1–6.
- Sato, Y. 2005. Flight ability of the podocarp bark borer, *Hirticlytus comosus* (Matsushita) (Coleoptera: Cerambycidae). *Journal of the Japanese Forestry Society* 87: 247–250.
- Schoeller, E. N., C. Husseneder, and J. D. Allison. 2012. Molecular evidence of facultative intraguild predation by *Monochamus titillator* larvae (Coleoptera: Cerambycidae) on members of the southern pine beetle guild. *Naturwissenschaften* 99: 913–924.
- Schoeman, P. S., H. V. Hamburg, and B. P. Pasques. 1998. The morphology and phenology of the white coffee stem borer, *Monochamus leuconotus* (Pascoe) (Coleoptera: Cerambycidae), a pest of Arabica coffee. *African Entomology* 6: 83–89.
- Schowalter, T. D. 2012. Insect responses to major landscape-level disturbance. *Annual Review of Entomology* 57: 1–20.
- Schroeder, L. M. 1997. Oviposition behavior and reproductive success of the cerambycid *Acanthocinus aedilis* in the presence and absence of the bark beetle *Tomicus piniperda*. *Entomologia Experimentalis et Applicata* 82: 9–17.
- Scriven, G. T., E. L. Reeves, and R. F. Luck. 1986. Beetle from Australia threatens eucalyptus. *California Agriculture* 40 (7–8): 4–6.
- Seetharama, H. G., V. Vasudev, P. K. V. Kumar, and K. Sreedharan. 2005. Biology of coffee white stem borer *Xylotrechus quadripes* Chev. (Coleoptera: Cerambycidae). *Journal of Coffee Research* 33: 98–107.
- Sharifi, S., I. Javadi, and J. A. Chemsak. 1970. Biology of the Rosaceae branch borer, *Osphrantheria coeruleascens* (Coleoptera: Cerambycidae). *Annals of the Entomological Society of America* 63: 1515–1520.
- Shi, Z. H., K. G. Cen, and S. Q. Tan. 1982. Studies on *Stromatium longicorne* (Newman) (Coleoptera: Cerambycidae). *Acta Entomologica Sinica* 25: 35–41.
- Shibata, E. 1986a. Dispersal movement of the adult Japanese pine sawyer, *Monochamus alternatus* Hope (Coleoptera: Cerambycidae) in a young pine forest. *Applied Entomology and Zoology* 21: 184–186.
- Shibata, E. 1986b. Adult populations of the sugi bark borer, *Semanotus japonicus* Lacordaire (Coleoptera: Cerambycidae), in Japanese cedar stands: Population parameters, dispersal, and spatial distribution. *Researches on Population Ecology* 28: 253–266.
- Shibata, E. 1989. The influence of temperature upon the activity of the adult sugi bark borer, *Semanotus japonicus* Lacordaire (Coleoptera: Cerambycidae). *Applied Entomology and Zoology* 24: 321–325.
- Shibata, E. 1994. Population studies of *Callidiellum rufipenne* (Coleoptera: Cerambycidae) on Japanese cedar logs. *Annals of the Entomological Society of America* 87: 836–841.
- Shibata, E. 1995. Reproductive strategy of the Sugi bark borer, *Semanotus japonicus* (Coleoptera: Cerambycidae) on Japanese cedar, *Cryptomeria japonica*. *Researches on Population Ecology* 37: 229–237.
- Shibata, E. 2000. Bark borer *Semanotus japonicus* (Col., Cerambycidae) utilization of Japanese cedar *Cryptomeria japonica*: A delicate balance between a primary and secondary insect. *Journal of Applied Entomology* 124: 279–285.
- Shintani, Y. 2011. Quantitative short-day photoperiodic response in larval development and its adaptive significance in an adult-overwintering cerambycid beetle, *Phytoecia rufiventris*. *Journal of Insect Physiology* 57: 1053–1059.
- Shintani, Y., Y. Ishikawa, and S. Tatsuki. 1996. Larval diapause in the yellow-spotted longicorn beetle, *Psacotheta hilaris* (Pascoe) (Coleoptera: Cerambycidae). *Applied Entomology and Zoology* 31: 489–494.

- Skiles, D. D., F. T. Hovore, and E. F. Giesbert. 1978. Biology of *Leptura pacifica* (Linsley). *Coleopterists Bulletin* 32: 107–112.
- Smith, C. I., and B. D. Farrell. 2005. Phylogeography of the longhorn cactus beetle *Moneilema appressum* LeConte (Coleoptera: Cerambycidae): Was the differentiation of the Madrean sky islands driven by Pleistocene climate changes? *Molecular Ecology* 14: 3049–3065.
- Smith, M. T., J. Bancroft, G. Li, R. Gao, and S. Teale. 2001. Dispersal of *Anoplophora glabripennis* (Cerambycidae). *Environmental Entomology* 30: 1036–1040.
- Smith, M. T., J. Bancroft, and J. Tropp. 2002. Age-specific fecundity of *Anoplophora glabripennis* (Coleoptera: Cerambycidae) on three tree species infested in the United States. *Environmental Entomology* 31: 76–83.
- Smith, M. T., P. C. Tobin, J. Bancroft, G. H. Li, and R. T. Gao. 2004. Dispersal and spatiotemporal dynamics of Asian longhorned beetle (Coleoptera: Cerambycidae) in China. *Environmental Entomology* 33: 435–442.
- Solomon, J. D. 1977. Frass characteristics for identifying insect borers (Lepidoptera: Cossidae and Sesiidae; Coleoptera: Cerambycidae) in living hardwoods. *Canadian Entomologist* 109: 295–303.
- Solomon, J. D. 1995. *Guide to insect borers in North American broadleaf trees and shrubs*. Washington, DC: U.S. Department of Agriculture, Forest Service, Agriculture Handbook AH-706.
- Stephen, F. M., V. B. Salisbury, and F. L. Oliveria. 2001. Red oak borer, *Enaphalodes rufulus* (Coleoptera: Cerambycidae), in the Ozark Mountains of Arkansas, U.S.A.: An unexpected and remarkable forest disturbance. *Integrated Pest Management Reviews* 6: 247–252.
- Swezey, O. H. 1950. Notes on the life cycle of certain introduced cerambycid beetles. *Proceedings of the Hawaiian Entomological Society* 14: 187–188.
- Takasu, F., N. Yamamoto, K. Kawasaki, K. Togashi, Y. Kishi, and N. Shigesada. 2000. Modeling the expansion of an introduced tree disease. *Biological Invasions* 2: 141–150.
- Tippmann, F. F. 1960. Studien über neotropische Longicornier III (Coleoptera, Cerambycidae). *Koleopterologische Rundschau* 37–38: 82–217.
- Togashi, K. 1987. Diapause termination in the adult cryptomeria bark borer, *Semanotus japonicus* (Coleoptera, Cerambycidae). *Kontyû* 55: 169–175.
- Togashi, K. 1990a. A field experiment on dispersal of newly emerged adults of *Monochamus alternatus* (Coleoptera: Cerambycidae). *Researches on Population Ecology* 32: 1–13.
- Togashi, K. 1990b. Life table for *Monochamus alternatus* (Coleoptera: Cerambycidae) within dead trees of *Pinus thunbergii*. *Japanese Journal of Entomology* 58: 217–230.
- Togashi, K. 1991. Larval diapause termination of *Monochamus alternatus* Hope (Coleoptera: Cerambycidae) under natural conditions. *Applied Entomology and Zoology* 26: 381–386.
- Togashi, K., S. Jikumaru, A. Taketsune, and F. Takahashi. 1994. Termination of larval diapause in *Monochamus saltuarius* (Coleoptera: Cerambycidae) under natural conditions. *Journal of the Japanese Forestry Society* 76: 30–34.
- Tozlu, G., S. Çoruh, and H. Özbek. 2010. Biology and damage of *Saperda populnea* (L.) (Coleoptera: Cerambycidae) in Aras valley (Kars and Erzurum provinces), Turkey. *Anadolu Tarım Bilimleri Dergisi* 25: 151–158.
- Trägårdh, I. 1930. Some aspects in the biology of longicorn beetles. *Bulletin of Entomological Research*. 21: 1–8.
- Villiers, A. 1980. Coléoptères Cerambycidae des Antilles Françaises. III. Lamiinae. *Annales de la Société Entomologique de France* 16: 541–598.
- Visitpanich, J. 1994. The biology and survival rate of the coffee stem borer, *Xylotrechus quadripes* Chevrolat (Coleoptera: Cerambycidae) in northern Thailand. *Japanese Journal of Entomology* 62: 731–745.
- Wallner, W. E. 1987. Factors affecting insect population dynamics: Differences between outbreak and non-outbreak species. *Annual Review of Entomology* 32: 317–340.
- Walsh, K. D., and M. J. Linit. 1985. Oviposition biology of the pine sawyer, *Monochamus carolinensis* (Coleoptera: Cerambycidae). *Annals of the Entomological Society of America* 78: 81–85.
- Wang, Q., G. Shi, and L. K. Davis. 1998. Reproductive potential and daily reproductive rhythms of *Oemona hirta* (Coleoptera: Cerambycidae). *Journal of Economic Entomology* 91: 1360–1365.
- Wang, Q., G. Shi, D. Song, D. J. Rogers, L. K. Davis, and X. Chen. 2002. Development, survival, body weight, longevity, and reproductive potential of *Oemona hirta* (Coleoptera: Cerambycidae) under different rearing conditions. *Journal of Economic Entomology* 95: 563–569.
- Ware, V. L., and F. M. Stephen. 2006. Facultative intraguild predation of red oak borer larvae (Coleoptera: Cerambycidae). *Environmental Entomology* 35: 443–447.

- Watari, Y., T. Yamanaka, W. Asano, and Y. Ishikawa. 2002. Prediction of the life cycle of the west Japan type yellow-spotted longicorn beetle, *Psacothea hilaris* (Coleoptera: Cerambycidae) by numerical simulations. *Applied Entomology and Zoology* 37: 559–569.
- Webb, J. L. 1909. Some insects injurious to forests: The southern pine sawyer. U.S. Department of Agriculture, Bureau of Entomology, Bulletin 58, Part IV, 41–56. Washington, DC: U.S. Government Printing Office.
- Wen, J., Y. Li, N. Xia, and Y. Luo. 1998. Dispersal pattern of adult *Anoplophora glabripennis* on poplars. *Acta Ecologica Sinica* 18: 269–277.
- Wermelinger, B., A. Rigling, D. Schneidermathis, and M. Dobbertin. 2008. Assessing the role of bark- and wood-boring insects in the decline of Scots pine (*Pinus sylvestris*) in the Swiss Rhone valley. *Ecological Entomology* 33: 239–249.
- Wickman, B. E. 1968. The biology of the fir tree borer, *Semanotus litigiosus* (Coleoptera: Cerambycidae), in California. *Canadian Entomologist* 100: 208–220.
- Williams, D. W., G.-H. Li, and R.-T. Gao. 2004. Tracking movements of individual *Anoplophora glabripennis* (Coleoptera: Cerambycidae) adults: Application of harmonic radar. *Environmental Entomology* 33: 644–649.
- Wollerman, E. H., C. Adams, and G. C. Heaton. 1969. Continuous laboratory culture of the locust borer, *Megacyllene robiniae*. *Annals of the Entomological Society of America* 62: 647–649.
- Yashiro, H. 1940. On the life-history of *Stromatium longicorne* Newman. *Bulletin of Okinawa Forestry Society* 1: 1–10.
- Yates, M. G. 1984. The biology of the oak bark beetle, *Scolytus intricatus* (Ratzeburg) (Coleoptera: Scolytidae), in southern England. *Bulletin of Entomological Research* 74: 569–579.
- Yoon, C., Y. H. Shin, J. O. Yang, J. H. Han, and G. H. Kim. 2011. *Pinus koraiensis* twigs affect *Monochamus saltuarius* (Coleoptera: Cerambycidae) longevity and reproduction. *Journal of Asia-Pacific Entomology* 14: 327–333.
- Yoon, H., and Y. Mah. 1999. Life cycle of the mulberry longicorn beetle, *Apriona germari* Hope on an artificial diet. *Journal of Asia-Pacific Entomology* 2: 169–173.
- Youngs, D. B. 1897. Oviposition of *Anthophilax attenuates*. *Entomological News* 8: 192.
- Zabecki, W. 1988. Role of cambio- and xylophagous insects in the process of decline of silver fir stands affected by the industrial air pollution in Ojcow National Park. *Acta Agraria et Silvicultura. Series Silvestris* 27: 17–30 [in Polish].
- Zhang, Q.-H., J. A. Byers, and X.-D. Zhang. 1993. Influence of bark thickness, trunk diameter and height on reproduction of the longhorned beetle, *Monochamus sutor* (Coleoptera: Cerambycidae) in burned larch and pine. *Journal of Applied Entomology* 115: 145–154.
- Zhang, X., and M. J. Linit. 1998. Comparison of oviposition and longevity of *Monochamus alternatus* and *M. carolinensis* (Coleoptera: Cerambycidae) under laboratory conditions. *Environmental Entomology* 27: 885–891.
- Zhao, R.-L., Z.-S. Lu, X.-H. Lu, and X.-Y. Wu. 1993. Life table study of *Anoplophora glabripennis* (Coleoptera: Cerambycidae) natural populations. *Journal of Beijing Forestry University* 15(4): 125–129.
- Zhou, J.-X., K.-B. Zhang, and Y.-Z. Lu. 1984. Study on adult activity and behavioral mechanism of *Anoplophora nobilis* Ganglbauer. *Scientia Silvae Sinica* 20: 372–379.



Taylor & Francis

Taylor & Francis Group

<http://taylorandfrancis.com>